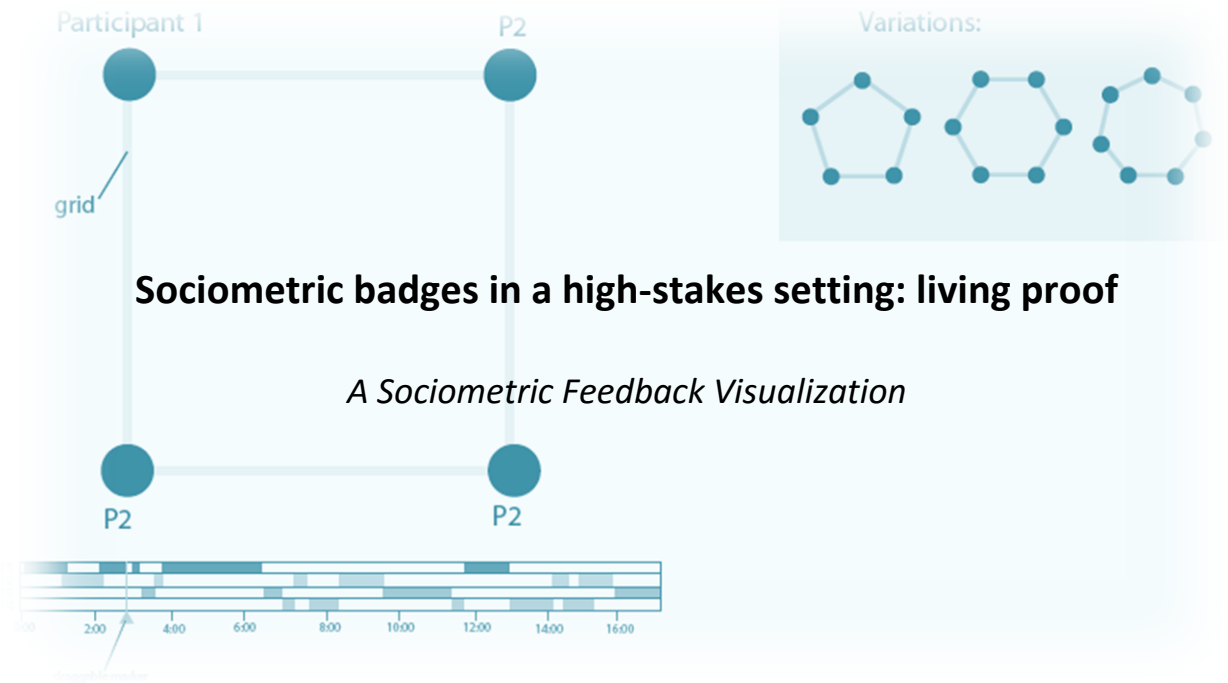

Sociometric badges in a high-stakes setting: living proof

A Sociometric Feedback Visualization

Creative Technology

BSc Thesis Project

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Abstract

In this paper, the research formulation and design process of a new sociometric feedback visualization are described in detail. A sociometric feedback visualization is used to present data gathered from human interaction behavior – information useful for research, self-evaluation and improving team performance at the workplace.

The visualization is designed using the Creative Technology method [9] at the University of Twente. A user test is carried out at the end of the process in order to evaluate the visualization and consider future work.

Acknowledgment

I would like to thank my project supervisors Khiet Truong and Elze Ufkes for their continuous assistance, as well as everyone who participated in my interviews and user testing.

1. Introduction

The purpose of this document is to detail the design process of a feedback visualization for the MIT Media Laboratory developed sociometric badge (or 'sociometer') – a technology primarily used to "automatically measure individual and collective patterns of behavior" [1]. The aim of the visualization is to reproduce data gathered by sociometric badges in a simple and minimal, yet informative manner, borrowing from and adding upon existing related visualizations. The design and research goals of the visualization are based on the requirements of the project client – the department of Psychology of Conflict, Risk and Safety (PCRS) at the University of Twente, The Netherlands. The PCRS is "increasingly enthusiastic about the possibilities of including new technology in (our) research projects", regarding the themes of conflict and crisis management, risk perception and risk communication, and the antecedents of risky, antisocial and criminal behavior [8].

The PCRS currently owns, and performs test group interactions with, multiple sociometric badges. The feedback visualization discussed here is designed to accommodate and potentially lessen the limitations of sociometric badges as used at the PCRS, as well as to provide an alternative to existing sociometric visualizations.

1.1 Sociometric Badges

Sociometric badges are a group interaction analysis technology developed by Alex Pentland [2] and his research team at the MIT Media Lab. A sociometric badge is worn around the user's neck, and is a compact device consisting of a built-in microphone, RFID, infra-red (IR) transceiver, accelerometer and bluetooth module, all used to gather data from the user during interaction at the workplace. Software for speech analysis and other sociometric parameters is used alongside these badges. By registering parameters such as speaking time, turn-taking, interruption, face-to-face interaction, physical distance, body motion and vocal features, the sociometric badge technology can be used to measure, analyze and potentially enhance team interactions.

Humanyze (previously known as Sociometric Solutions), the company behind the sociometric badge technology, exists to assist organizations with "teamwork and engagement" [3] by detecting communication problems and boosting work performance [4]. Parallel to sociometric hardware, the MIT and Humanyze have worked on multiple feedback visualizations in order to aid Humanyze's mission, ranging from prototype data representations such as Meeting Mediator [5] and DynaMeet [6] to more

commercially viable systems such as Humanyze's own Wyze [7] data visualization. The sociometric feedback visualizations are a key component of enabling organizations and their individual members to analyze and enhance meeting behavior and productivity.

Figure 1: *The sociometric badge, portable and compact.*

1.2 Feedback visualization

All data gathered by sociometric badges is analyzed and output by specialized software. Subsequently, this information can be displayed through data visualization for user feedback and behavior analysis purposes. The two most well recognized of these feedback visualizations, developed by Humanyze (Sociometric Solutions) and the MIT Media Lab during the initial stages of wearable sociometric technology, are DynaMeet and Meeting Mediator.

DynaMeet, developed by Humanyze, relies on post-use sociometric badge feedback (non-real-time), covering aspects such as user interactivity, participation and dominance through multiple graphs and visualizations. Meeting Mediator, developed at the MIT Media Lab, relies on a single screen, real-time feedback visualization (designed as a mobile application) which displays user speech dominance, group interactivity and balance in participation. The aim of these sociometric feedback visualizations is to

present multiple types of behavioral data either as an overall event summary or per fragment of time (the maximum time resolution of the sociometric badges used at the University of Twente is data at every 0.5 second). The feedback visualization designed for the assignment discussed here shares this aim, as well as the vision to create an easy-to-grasp, simple but in-depth self-evaluation tool for small, closed-door team meetings. Beyond DynaMeet and Meeting Mediator, this document also examines Liqin Zhang's ViSo feedback visualization, Wyze and related visualizations in the field of interaction behavior studies.

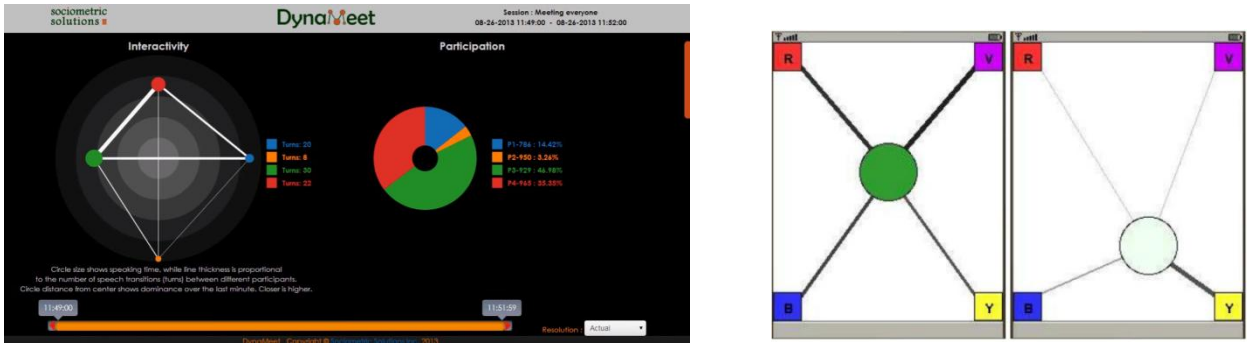


Figure 2: *Examples of DynaMeet (left) and Meeting Mediator (right).*

1.3 Challenges

The development of a sociometric feedback visualization for this assignment is concerned with the type of feedback, the efficiency and effectiveness of data presentation and the validity of the feedback as a tool for behavior evaluation. An initial challenge is to determine the type of feedback – visual, aural or haptic (the sense of touch)? The design will be adapted to the sociometric technology used by the PCRS at the University of Twente, which currently supports only non-real-time feedback. The most practical, accessible, and affordable decision for this limitation is to develop a purely visual form of feedback. This choice will only require the presence of a screen (fixed or portable) and no additional wearable technology.

The efficiency and effectiveness of data presentation is one of the primary, purely design-oriented concerns of the visualization. Sociometric badges collect multiple types of behavioral data, demanding a decision between a complex interface with numerous types of data, or a simpler interface with fewer

types of data. Furthermore, the types of data observed drastically affect the design of the visualization – for example speech time can be expressed with a single numerical value, but consistency of speech will require a combination of multiple variables. The challenge here is to find a combination of a sufficient variety of data with an easy-to-understand visualization (efficiency). The data presented must also be effective – i.e. it must be logical and useful to the examiner.

Possibly the most important element of the feedback visualization is the validity of the feedback. The aim of sociometric analysis is to provide meaningful and accurate information regarding "collective patterns of behavior" and "social affinity among individuals working in the same team" (among other elements) [1]. The data visualized must be unambiguous and in agreement with existing studies of human behavior and interaction. This challenge directly affects the selection of the most suitable variables observed in sociometric badge data, for the purpose of the visualization.

An additional challenge, more specific to the requirements of the PCRS, is to improve data gathering and output speed. This challenge concerns the output Excel data file containing sociometric badge data, and how its contents can be transferred easily to the feedback visualization.

1.4 Research questions

Two key research questions have been formulated in order to address the challenges of the project, determine the research topics and types, and structure the design process of the feedback visualization.

1. How well will a user be able to perceive a sociometric badge feedback visualization of data from an enclosed, around-the-table group meeting, as **designed** in this project? (RQ 1)
2. To what degree is the feedback visualization interpreted as relating to speech dominance? (RQ 2)

The first research question covers the design of the visualization, and all related challenges; it concerns the application of the principles of design and data visualization, as well as the technology behind the visualization.

The second research question deals with the psychology of human interaction and behavior, and how it is used within the visualization. This research question also guides the selection of data for the visualization, as well as the theory behind the methods and choices for representing this data.

2. Design process: the Creative Technology method

The design process discussed in this document will adhere to the four-stage, iterative method developed for the study of Creative Technology at the University of Twente, as described by Angelika Mader and Wouter Eggink [9]. The four stages, or phases, of the Creative Technology design process are ideation, specification, realization and evaluation, leading into each other respectively. These phases occur consecutively, but are also navigable in reverse and simultaneously so as to allow for adjustments, and thus improvements, to every step and part of the design process. For the purposes of this document, each of these phases is examined in relation to the development of a sociometric badge feedback visualization.

The ideation phase concerns the 'birthing' of the project. This phase revolves primarily around secondary research and idea generation. User and stakeholder/client requirements are determined with assistance from PCRS. Technology and related psychology topics are examined, with the Humanyze research database as a starting point. Considering the theme(s) of the project – service, interaction and experience ideas are generated through brainstorming, sketches, user scenarios and mockups. These ideas can be evaluated with potential users, the project supervisors and the client. If necessary, the steps are repeated or revisited – this applies to each phase of the design process (feedback loop).

The specification phase addresses the tools and methods used to develop the visualization. The functional specification is used to determine the ins and outs of the feedback interface and how the system will be perceived by the user; what data will be gathered from the badge, which behavioral aspects will be used and how they will be compared, as well as how the data will be presented. The experience specification determines possible user response to the system through user scenarios and storyboards, along with further research and user interviews. More detailed mockups are then developed for the purposes of a prototype.

The realization phase is where the construction of the visualization takes place. The decomposition and integration of components are used to design all elements of the interface and to determine how they will function together. These components are assembled to work together through the integration. The system is then evaluated, and all stages of the design process up to this point are referred to if necessary.

The final phase of the design process, the evaluation, consists of user tests and system tests (flaws, glitches, revisions). The product is also compared to existing solutions, e.g. Humanyze's Wyze or

DynaMeet. It is then determined if the product needs adjustment, and the previous phases are revised if necessary. Following a background literature review, the four stages of the Creative Technology design process are documented in detail.

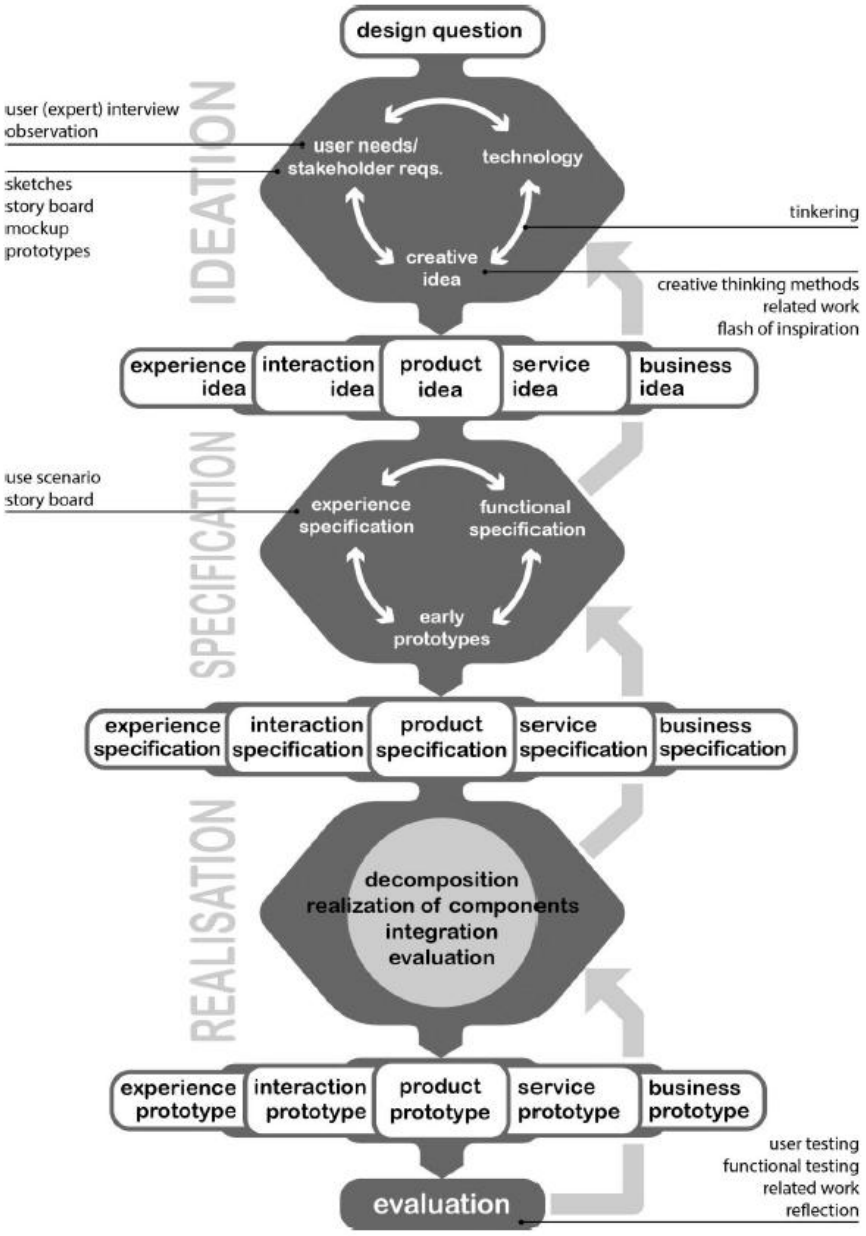


Figure 3: *The Creative Technology design process.*

3. Background literature

The following section is an introduction to the assorted background literature, covering topics relevant to the theme and design process of the project. These topics include interaction analysis, data visualization and state-of-the-art.

3.1 Interaction analysis

The key purpose of sociometric technology is to analyze human (group) interaction [1]. Robert Freed Bales (1916-2004), a well-recognized sociologist, "pioneered the development of systematic methods of group observation and measurement of interaction processes" [10]. Using his SYMLOG system (Systematic Multiple Level Observation of Groups), Bales outlined three dimensions of interaction in groups – dominance/submission (or non-dominance), friendliness/unfriendliness and acceptance of authority/non-acceptance of authority. The MIT Media Lab regards analysis of the first dimension of SYMLOG, dominance/non-dominance, as essential to sociometric badges since "dominant behavior is a key determinant in the formation of a group's social structure, and consequently group dynamics" [5]. The group behind Meeting Mediator, the real-time feedback visualization for sociometric badges, views the relationship between dominance and group dynamics as valuable for the provision of interventions for performance improvement.

For the purposes of the project discussed in this document, the dimension of dominance/non-dominance will be a primary focus of the design and research process (specifically addressing RQ 2).

3.2 Data visualization

All existing sociometric badge feedback visualizations are in essence data visualizations. Design and data visualization principles are used to make visualizations effective, efficient and appealing. Design principles applicable to feedback visualization include the topics of object/item scale, color, transparency, balance, hierarchy, contrast, grid, movement, rules and composition [11]. These principles (and possibly more) will be examined and applied during the design process of the feedback visualization.

Statistician, artist and data visualization specialist, Edward Tufte, describes nine principles of data visualization, covering the themes of data presentation, distortion, coherence, comparison, detail,

purpose and description [12]. These principles will be discussed in detail throughout the phases of the design process.

3.3 State-of-the-art

Two relatively well-documented sociometric badge feedback visualizations are DynaMeet and Meeting Mediator. While not the most recent developments in the area of sociometric feedback, these visualizations outline the basic components of real-time and non-real-time feedback. A visualization prototype, ViSo, developed by Liqin Zhang at the University of Twente (bachelor thesis), is also a notable and useful example for this project.

3.3.1 DynaMeet

Humanyze's own early development feedback visualization, DynaMeet consists of multiple sections (views) displaying various types of interaction behavior [6].

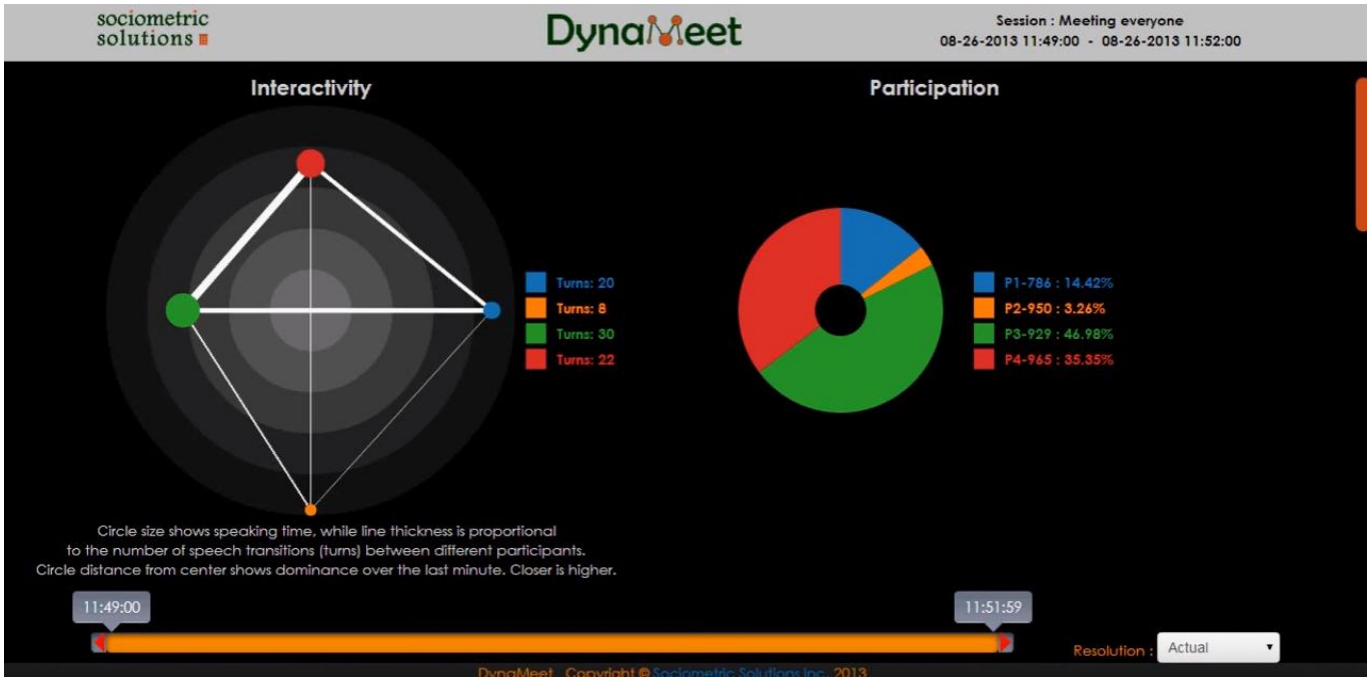


Figure 4: *DynaMeet main view – interactivity and participation.*

The main view looks at user interactivity and participation. These are based on sociometric badge analyses such as speaking time, speech transition and dominance. The more unique and interesting of these two sub-visualizations - the interactivity circle, presents each participant as a colored sphere. The closer a sphere is to the middle, the higher the speaking percentage. The thicker a line between two

participants is, the more turns have been taken between them. The interactivity circle most notably represents Tufte's principle of presenting many numbers (multiple sets of data) in a small space [12].

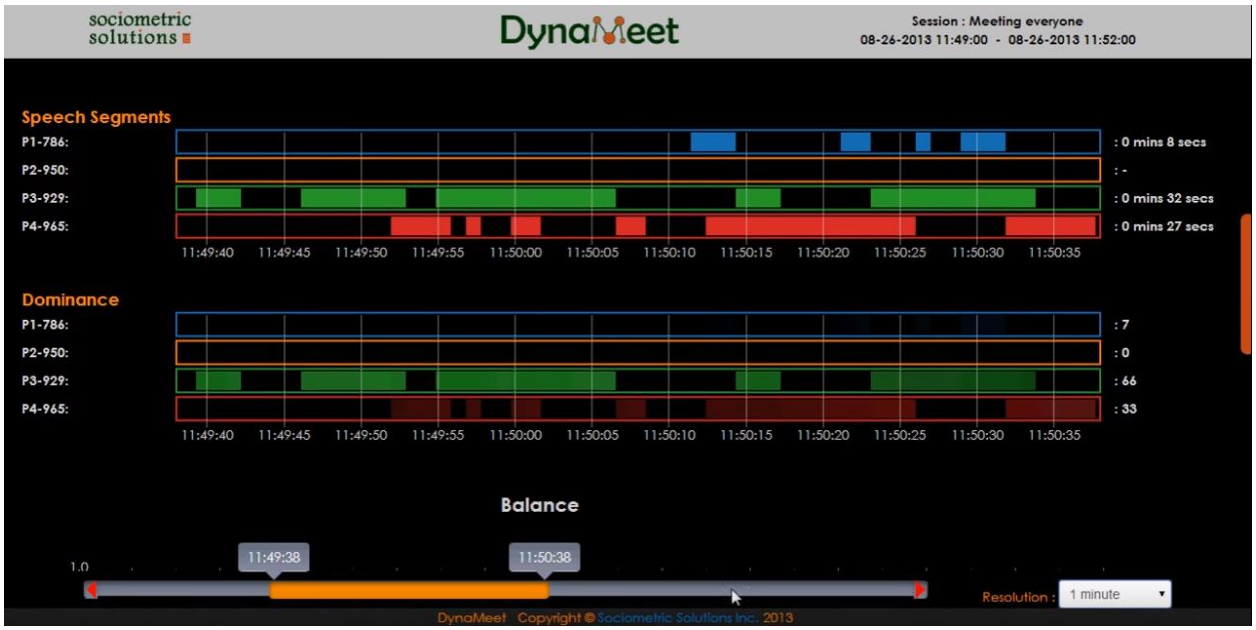


Figure 5: *DynaMeet speech dominance.*

The DynaMeet speech dominance view displays a detailed time line where each participant's speech contribution can be observed individually and in relation to other participants'. This type of timeline serves as inspiration for the timeline section of ViSo, as well as a timeline designed in this project.

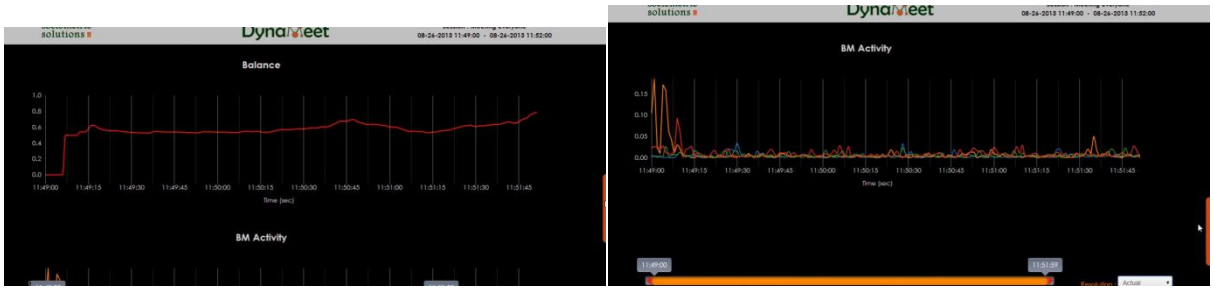


Figure 6: *DynaMeet interaction balance (left) and body movement (right).*

Other data seen in DynaMeet includes two line graphs – the interaction balance, derived from speech and turn-taking metrics over the last minute (higher value = more balanced conversation), and BM (body movement) activity calculated at a resolution of one second.

DynaMeet is a valuable tool in the sense that it presents multiple sociometric badge measurements on a single (scrollable) page. One concern is how it connects all of these elements, which relates to Tufte's principles of provoking thought about the subject at hand, and serving a reasonably clear purpose [12]. If viewed as a single visualization, DynaMeet is a collection of statistics, with the interactivity circle visually connecting numerous sets of data most effectively. If viewed as a list of separate visualizations, DynaMeet is an in-depth sociometric badge analysis tool. Evaluating all of the data presented in DynaMeet at a glance is challenging, and perhaps DynaMeet is a tool more suited to researchers rather than the participants themselves.

3.3.2 Meeting Mediator

Meeting Mediator (MM), developed by the MIT Media Lab as a real-time sociometric visualization for portable devices, is comparatively simpler than DynaMeet as an interface [5]. Designed to be viewed on the smart phone screens of participants as they interact, MM is suitably a single visualization. Like DynaMeet's interactivity circle, MM presents multiple sets of data in a small space.

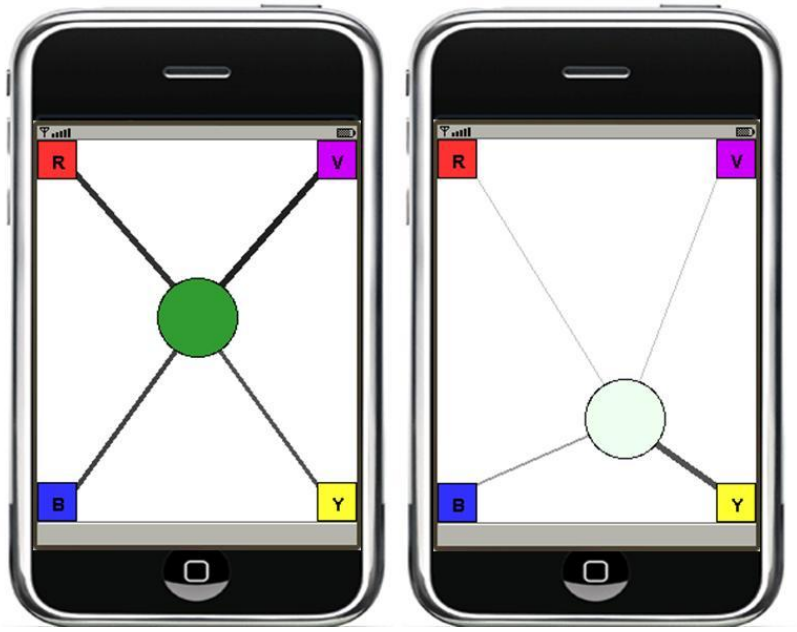


Figure 7: *Meeting Mediator (MM), fully displayed on a single smart phone screen.*

Tested for interactions of four participants, MM consists of four squares each representing a participant in a corner. Line thickness denotes speaking time; the circle color displays the group interactivity level

and the circle position represents the participation balance (the latter two are determined by a combination of sociometric badge measurements).

More than just a data graphic, MM establishes the sense of a physical space, where the dominance of a given participant 'pulls' the circle toward them. This enables the user of the application to quickly determine what is going on at any instance. The use of opaque and transparent colors aids in the simplicity of MM's circle design [11]. However, the limited physical scope of the visualization also limits the amount of data that can be presented. Meeting Mediator serves as a primary visual inspiration for the project discussed here, due to its user-friendly simplicity and capability to visualize multiple data sets simultaneously.

3.3.3 ViSo

Similar to DynaMeet, ViSo is a collection of data visualizations; it is also more reliant on the principle of presenting multiple data sets in a small space.

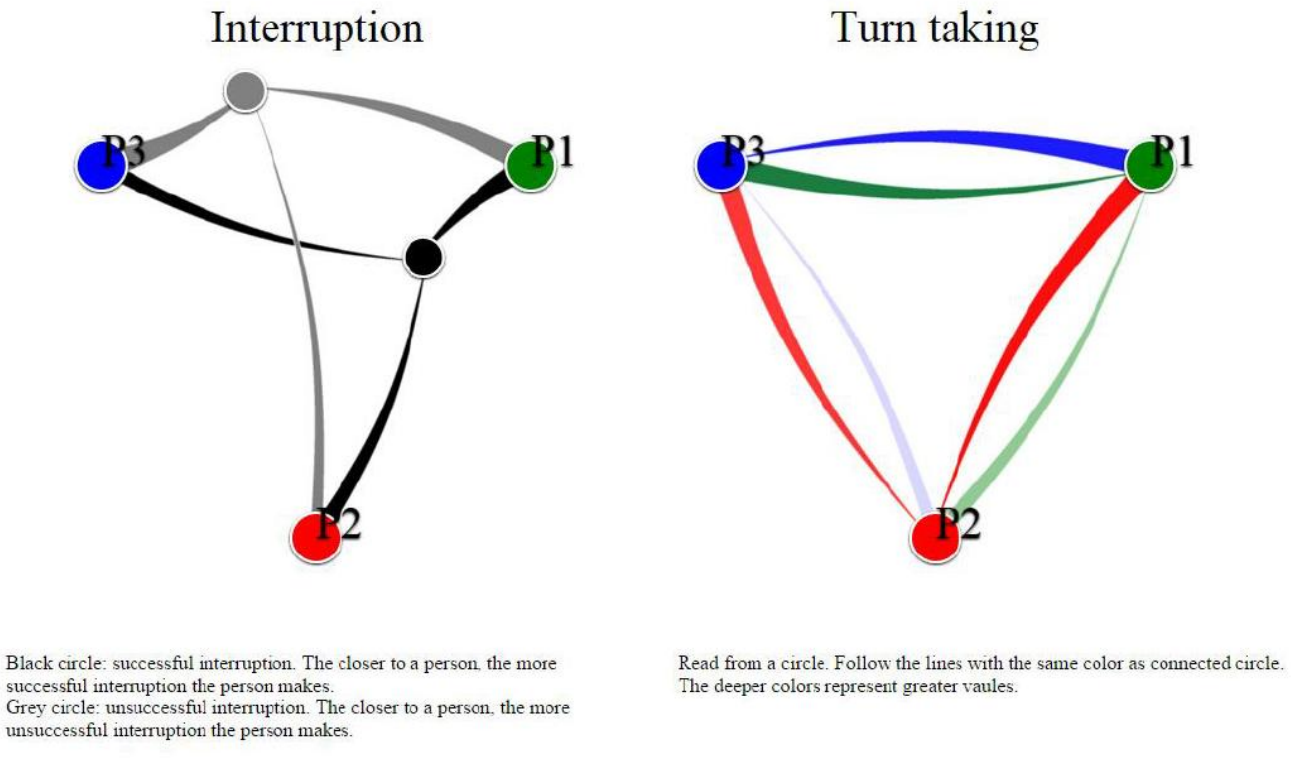


Figure 8: *ViSo interruption and turn taking. Successful and unsuccessful interruption data presented in a single visualization. Use of color variation.*

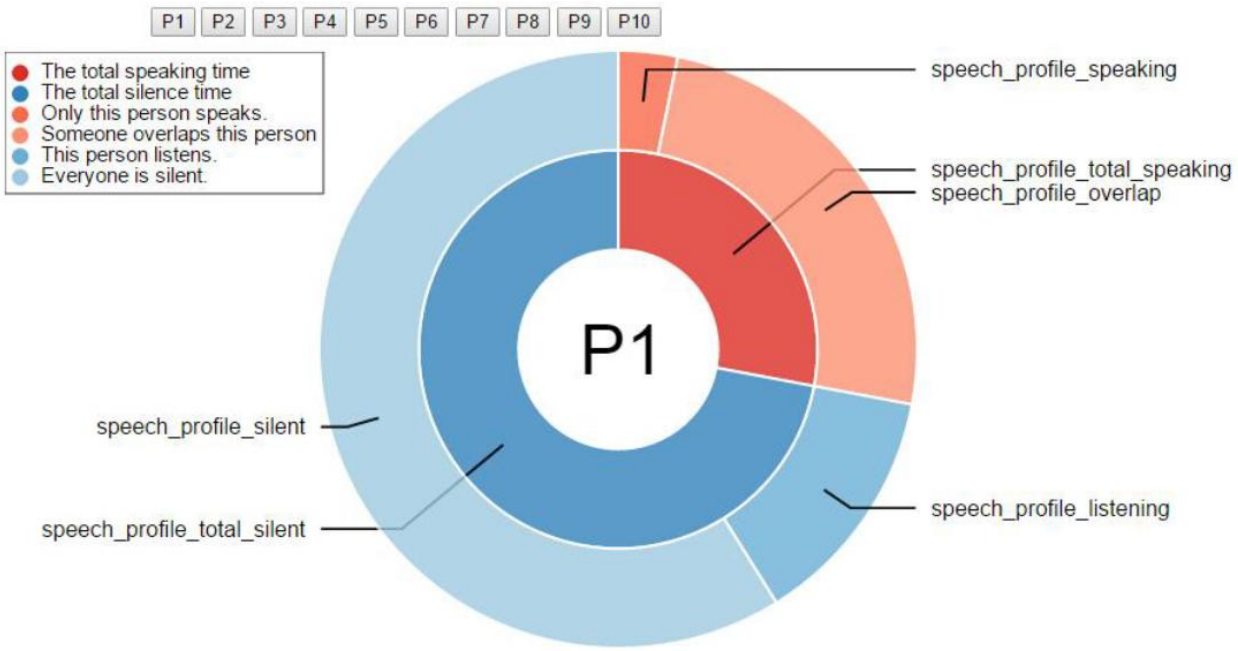


Figure 9: *Multiple sets of data in ViSo's speech profile.*

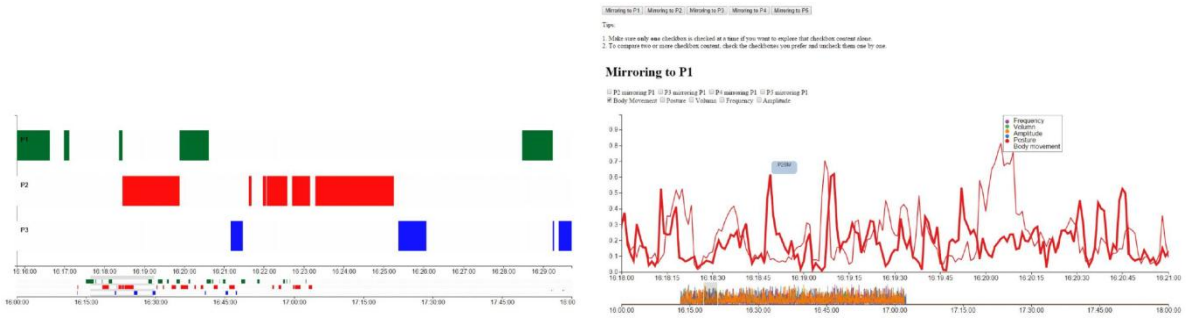


Figure 10: *ViSo participation (left) and mirroring (right). The design here is inspired by DynaMeet's speech/dominance timeline.*

ViSo covers four measurement categories derived from the sociometric badges in use at the University of Twente (upon which this project is also based). All information is labeled and the degree of detail is adjustable through the ability to zoom in and out of the timeline-based visualizations, i.e. interactive change of the time resolution displayed. The design choices follow data visualization and design principles effectively, however, like DynaMeet, there is no explicit purpose-related connection among all of the ViSo visualizations.

Of interest is the decision to make mouse-over (hover) pop-ups in the ViSo interruption and turn-taking section. This creates an additional layer of data which is accessed optionally through the user's interaction.

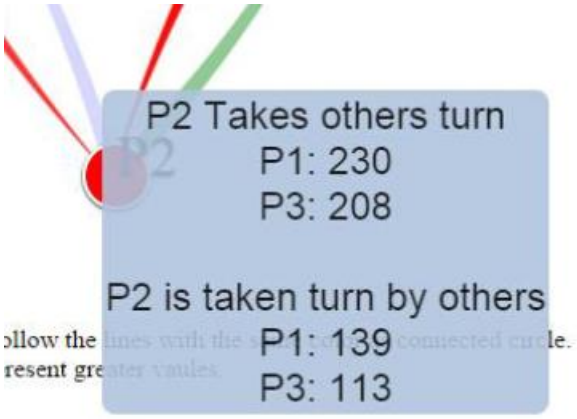


Figure 11: *ViSo mouse-over data. A possible inspiration for this project.*

3.3.4 Other: Conversation Clock

A recent, well-recognized, speech-oriented project is the Conversation Clock, developed by Tony Bergstrom and Karrie Karahalios at the University of Illinois [16] [17]. Acting as a real-time feedback visualization of conversation, or a 'social mirror', the Conversation Clock concentrates on vocal mimicry and speech dominance [17]. The Conversation Clock provides inspiration for this project in two ways – it relies on 1 (one) minute segments of speech in order to separate the data, and it analyzes speech dominance (RQ 2). Both of these topics will be examined during the design process of the project prototype.

The Conversation Clock is projected on a round table, where the conversation participants are seated. It consists of 'circles' which represent the speech audio waveforms. After one minute of speech, a circle is completed, and shrinks towards the center of the visualization; the new outermost set of data (circle) represents the new, current minute. A big plus of the clock visualization is the efficiency of data presentation - minimal, clear, single, shared interface with real-time feedback.

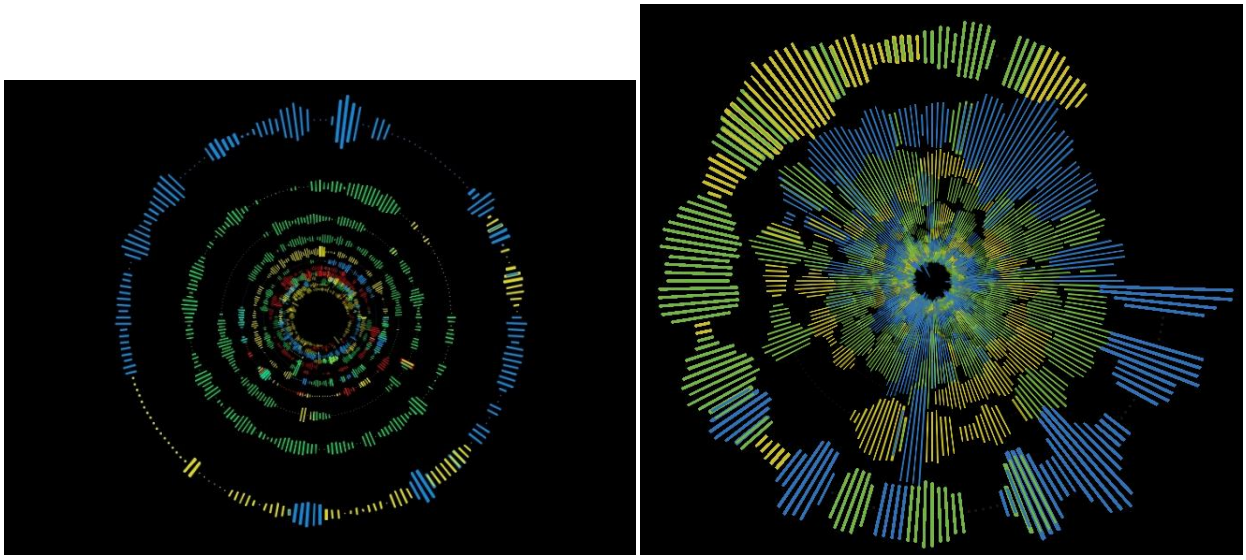


Figure 12: *The Conversation Clock. Lower speech activity (left) and speech dominance (right).*

Each speech circle relies on Tufte's principle of presenting many numbers (multiple sets of data) in a small space [12], which is done with various shapes, patterns and color codes (Figure 13). This design is elegant; however it may appear abstract and ambiguous to the uninitiated due to a lack of a key/legend or labels.

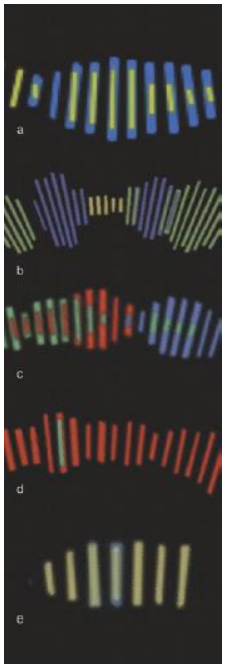


Figure 13: *Conversation Clock patterns [17]:*

a. *Concurrent speaking (overlap)*
b. *Delayed turn-taking*
c. *Traditional turn-taking*
d. *Agreement*
e. *Agreement*

3.3.5 Other: Wyze

Wyze is the latest sociometric application developed by Humanyze [7]. Oriented towards enhancing (team) productivity at the workplace, Wyze is distinguished by its long-term tracking of team productivity, observing trends with a benchmark and score system in order to encourage teams and individuals to improve. Wyze is said to have significantly boosted the productivity of multiple existing organizations; however, little is publicly know about this feedback application. From what can be seen of the existing mockups, Wyze relies on line-graph focused data visualization, with multiple pages and sections, in a sense similar to DynaMeet.

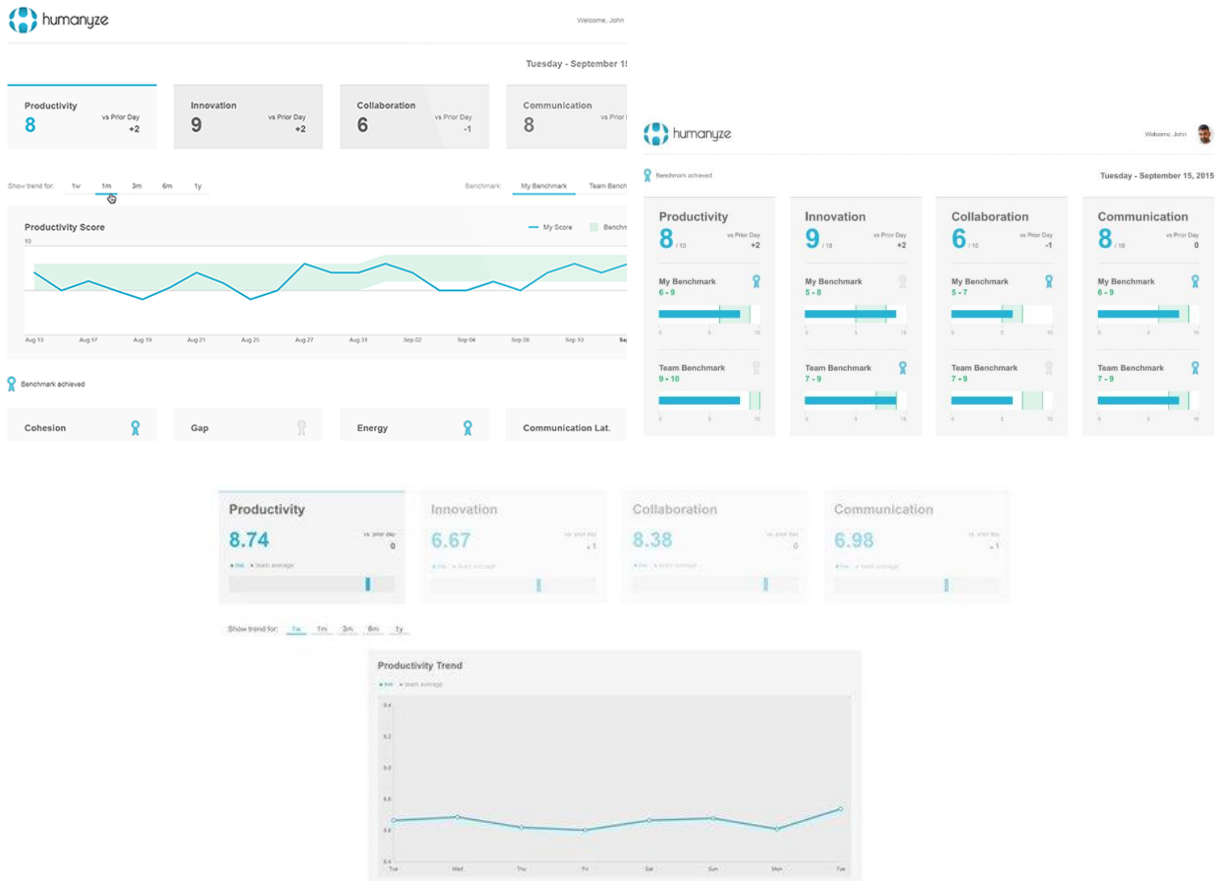


Figure 14: *Multiple 'pages' from the Wyze mockup. Team-oriented, work-themed topics are examined and 'scored' after days/weeks of tracking.*

3.4 Improving upon existing designs

The visualizations discussed in this section follow key design principles effectively, with some innovating more than others. A solid balance between practicality and aesthetics is required when developing a new data visualization. The sociometric feedback visualization developed for this project addresses the existing products as follows:

- DynaMeet presents multiple graphics with various types of information. The interactivity graph successfully integrates multiple types of data, and serves as inspiration for this project. As a self-evaluation tool, this project aims to improve upon DynaMeet by reducing the visualization to a single screen. Everything will be presented on a fixed page, and the design will move away from standard graphs to a more personalized design.
- Meeting Mediator and its specific design serve as the main inspiration for this project. However, Meeting Mediator's design is limited by its platform (smart phone) – labels, keys/legends and more detailed information are absent. The project discussed here is designed for a larger screen (desktop, laptop, touchpad), and will contain a timeline, participant representations with various data, and interactivity. As a post-interaction (non-real-time) visualization, a user of this project's visualization is also assumed to be capable of interpreting more data due to a lack of external pressure (no time limit or performance nervousness.)
- Like DynaMeet, ViSo presents multiple sets of useful data in sub-visualizations, but does not make an explicit connection among all of the data types. The visualization designed in this project will integrate various data in a single main visualization, and will attempt to connect all of the data under a single topic – speech dominance. This is a more specific focus, but also enables the visualization to be designed for a greater range of users for self-analysis or self-evaluation.
- The Conversation Clock is a rich data visualization, but like Meeting Mediator is abstract in its design. Uninitiated users require thorough explanation prior to usage. The feedback visualization discussed here will represent fewer data types, but will also have a clearer focus and a design more accessible to beginner users.
- Wyze is a complex application with many pages, statistical data and graphs. The final product of this project will be less complex and more accessible; this is important when users want to analyze data but lack the time or patience at a given instance.

The final prototype of the visualization will borrow from these existing designs, but will differentiate itself in its scope, focus, accessibility, usage (degree of interactivity) and aesthetics.

4. Ideation

This section addresses the initial steps of designing the feedback visualization. The stakeholder and user requirements are determined, and service, interaction and experience ideas are generated through brainstorms, sketches and mockups.

4.1 Stakeholder requirements

While there are no restrictions on the visual design of the product or the level of user interactivity, three stakeholder requirements affect the purpose and scope of the project as follows. The PCRS requires:

1. A visualization with meaningful data. The project must rely on the data output solely from the sociometric badges used by the PCRS at the University of Twente. Sample data is available, as well the possibility to carry out tests with the sociometric badges.
2. A purpose for the data chosen. The interaction analysis must serve a goal. Why is the selected data tested? What is the scientific or academic validity of the analysis? How can this benefit participants, organizations and/or researchers in the field of sociometry and human interaction?
3. A visualization preferably suited to post-interaction analysis. The sociometric badges in use do not support real-time feedback availably. As such, it is most realistic to develop a feedback visualization which adheres to this limitation.
4. An additional requirement is to take the limitations of the prior development, ViSo, into account. If possible, addressing the issue of the slow and laborious transfer of sociometric Excel data to the feedback visualization can be helpful.

4.2 User requirements

The user group for this project is all group interaction participants in the work-place – work and project teams, organization employees, university students and possibly school students. Primary research and user testing will concentrate on student project teams at the University of Twente and a small company team if possible. For the purposes of evaluation and user feedback, the specific target group chosen for this study is young adults (aged 16 to 30) with team-work experience (either academic or work-related). Since most of the user testing and evaluation are carried out with university students, the lower age limit is extended from 18 to 16 years. The reason for this age group choice is that young adults are more likely to be familiar with current technology, and are also likely to be part of a future work force which

will be more reliant on sociometric analysis. Since the sociometric badge feedback visualization is an evaluation tool, it will also be accessible to researchers.

The initial user requirements are assumed to be an easy-to-use and easy-to-understand visualization, based on the existing design and data visualization principles discussed in this document. Further requirements will be determined through user feedback in the following phases of the design process.

4.3 Brainstorms and sketches

Following the initial background literature and stakeholder/user requirements, early design ideas of for the visualization are conceptualized on paper.

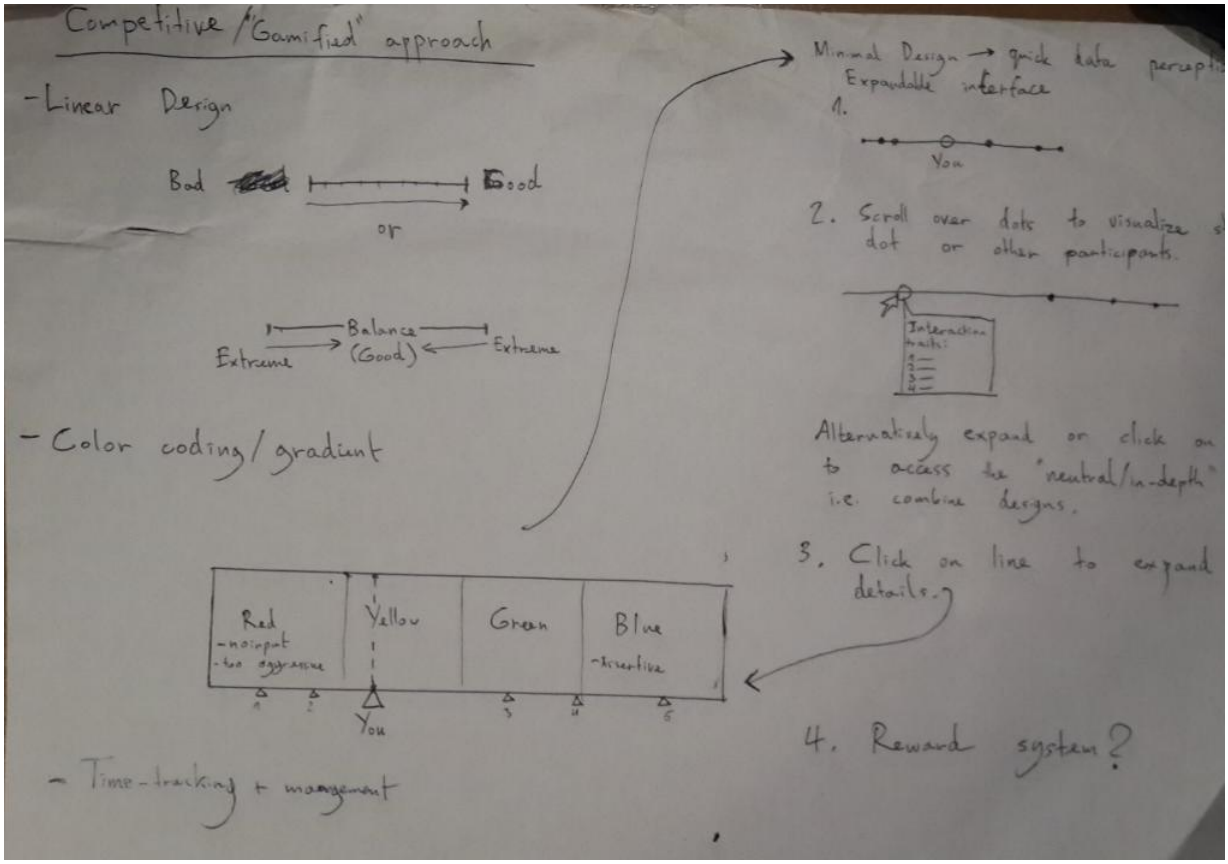


Figure 15: *An early sketch considers a 'gamified' approach, where users are directly advised on how to behave.*

The initial brainstorm examines a 'good versus bad' scale system, where users are explicitly advised on how to adjust their behavior (Figure 15). This idea is an attempt to innovate through user competitiveness and a smart advice system. However, these concepts are ethically complicated and far-

fetched respectively. The Meeting Mediator group values the possible benefits of dominant behavior (encouraged through competitiveness), but does not directly encourage it through its system [5]. The scope of automated sociometric measurement is currently too narrow to be able to develop a system which can provide sound behavior-related advice.

This early brainstorm also considers the possibility to have detailed mouse-over data information, which can be seen in ViSo.

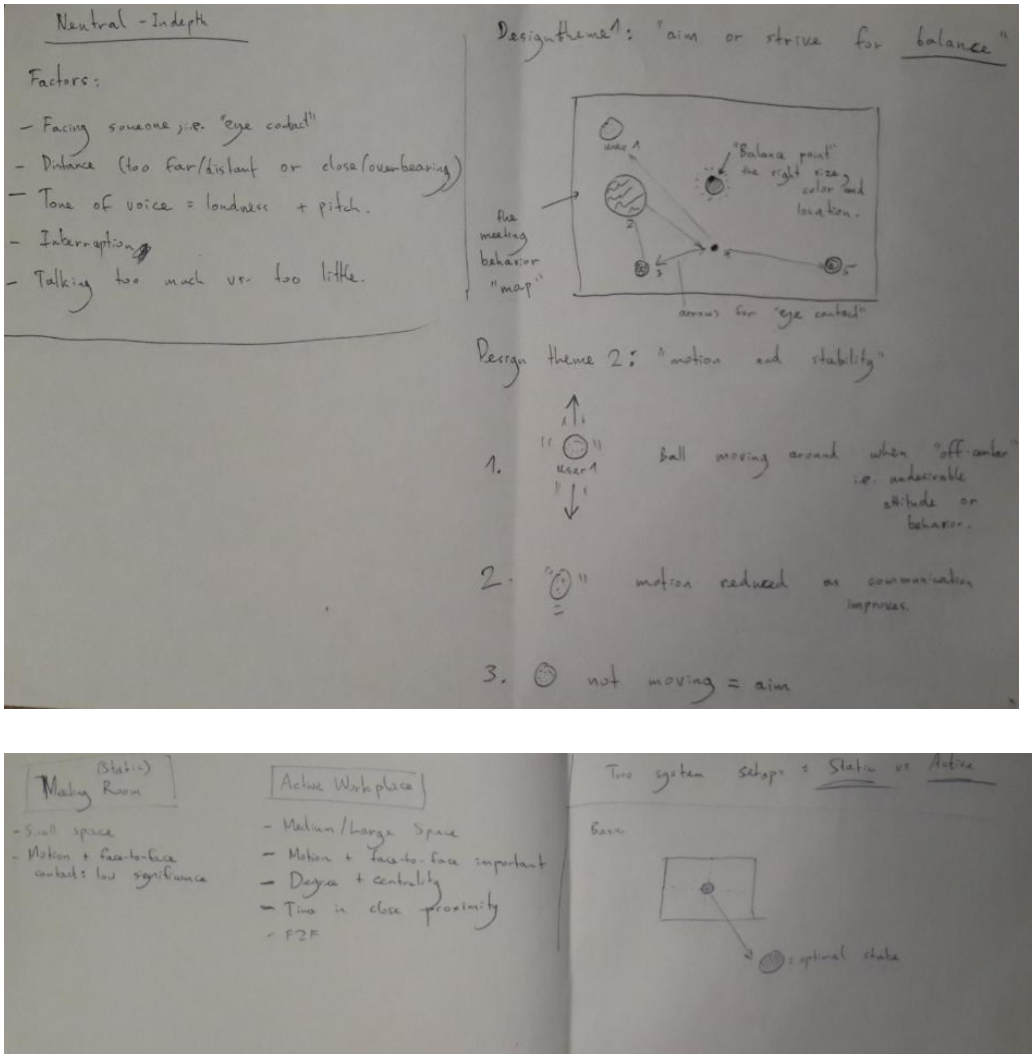


Figure 15: *A more realistic later brainstorm, taking sociometric measurements and types of meetings into consideration. Shapes and motion are inspired by existing visualizations such as Meeting Mediator.*

A second, more grounded approach is examined in a later brainstorm phase (Figure 16). Here a more neutral and indepth feedback system is conceptualized. User representations and moving visuals take

inspiration from DynaMeet (different shaped and colored circles or spheres) and Meeting Mediator (moving or changing-over-time visualization). A centered, 'optimal' state like that of MM or the DynaMeet interactivity circle is proposed. This sketch is also preferred by the PCRS over the initial one. With this in mind, work is initiated on a more detailed mockup of a possible system.

Data variables are considered, based on the main sociometric badge measurements found in the badge output Excel file (Figure 16). Due to the project's theme of speech dominance, speech-related variables are used in the visualization mockups; these are discussed in detail in the specification phase.

Key	Session	B-867	B-894	B-902	B-957
BM_bm	Test 2	0.043004	0.037238	0.024043	0.023967
BM_activity	Test 2	0.000291	0	0.001786	0
BM_rate	Test 2	0	0	0.000245	0
BM_consistency	Test 2	0.99961	1	0.996007	1
posture_activity	Test 2	0.26926	0	1.304085	0
posture_rate	Test 2	1.49E-18	0	0.165663	0
speech_profile_speaking	Test 2	10.5	28	29	36.5
speech_profile_overlap	Test 2	141	88	74.5	83.5
speech_profile_listening	Test 2	126.5	162	174.5	158
speech_profile_silent	Test 2	22	22	22	22
speech_profile_total_speaking	Test 2	151.5	116	103.5	120
speech_profile_total_silent	Test 2	148.5	184	196.5	180
speech_dominance	Test 2	0.21909	0.182921	0.428319	0.16967
audio_front_volume	Test 2	0.027327	0.025543	0.027895	0.041776
audio_front_vol_consistency	Test 2	0.989557	0.990279	0.989585	0.984666
audio_back_volume	Test 2	0.031862	0.029532	0.031307	0.036369
audio_back_vol_consistency	Test 2	0.988073	0.988826	0.988236	0.986667
interactions_combined_B-867	Test 2	0	300	300	300
interactions_combined_B-894	Test 2	300	0	300	300

Figure 17: *Some of the main sociometric badge output, as seen in the badge Excel file.*

4.4 Mockup 1

A clear and specific mockup is developed for the client, as well as for potential user feedback.

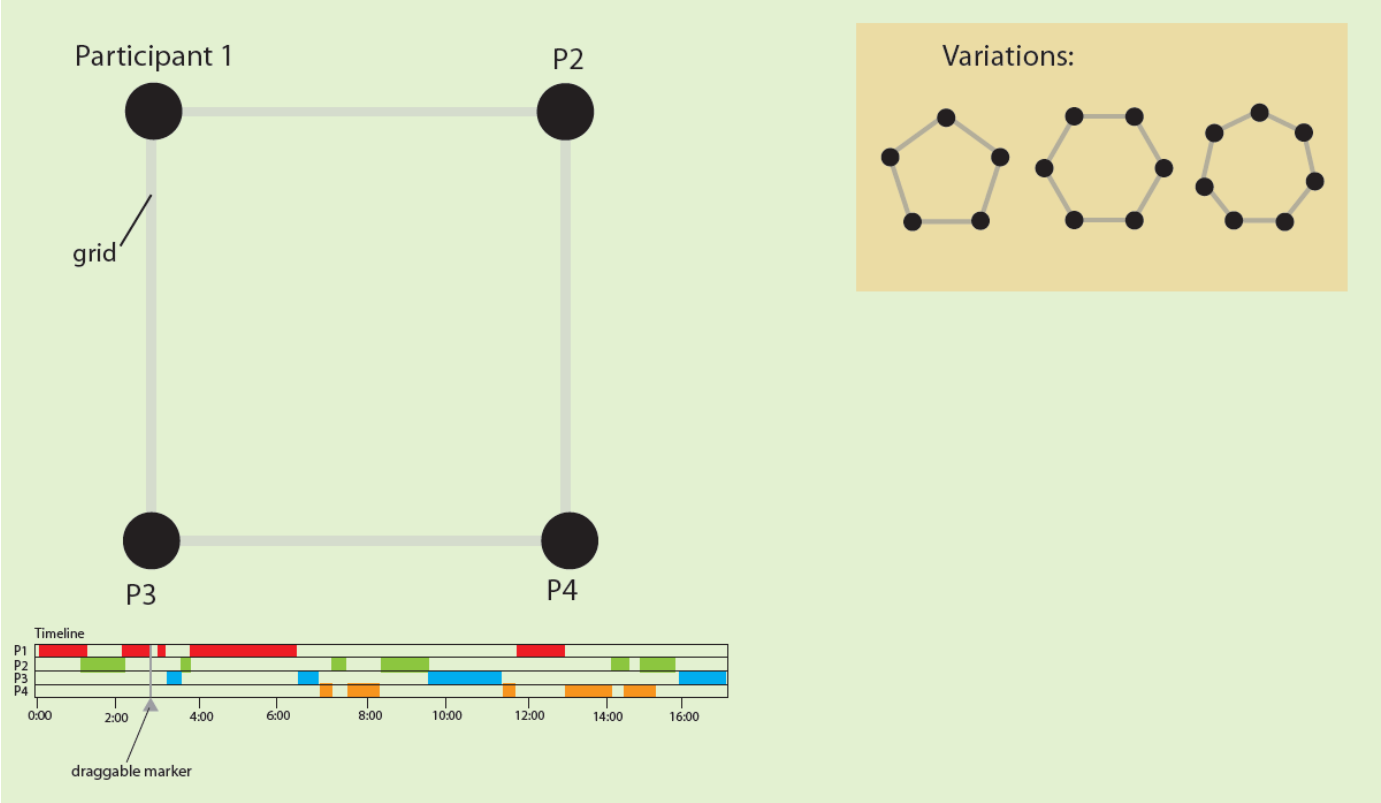


Figure 18: *The basis for mockup 1.*

In the pursuit of creating a grounded and believable design akin to that of DynaMeet or Meeting Mediator, multiple sources of inspiration are combined and adapted or modified (Figure 18). With the aim of developing an easy-to-understand visualization, the four-corner frame of MM is borrowed as a 'grid' for the participant-representing circles (referred to as 'bubbles'), inspired by the circles in DynaMeet. Multiple polygonal grid variations are considered to address the limitation of four participants in MM. A timeline resembling those of DynaMeet and ViSo is also presented. This 'separate' visualization is in fact intended to be linked to the grid visualization. Of note here is the 'draggable' marker. This marker is the link between the two sub-visualizations; it is also a design choice which follows Tufte's principle of engaging or encouraging the user to compare data through interactivity [12]. The marker allows users to scroll through the timeline to specific points determined by the time resolution. At each point on the timeline, interaction events relevant to the grid area of the visualization can be observed.

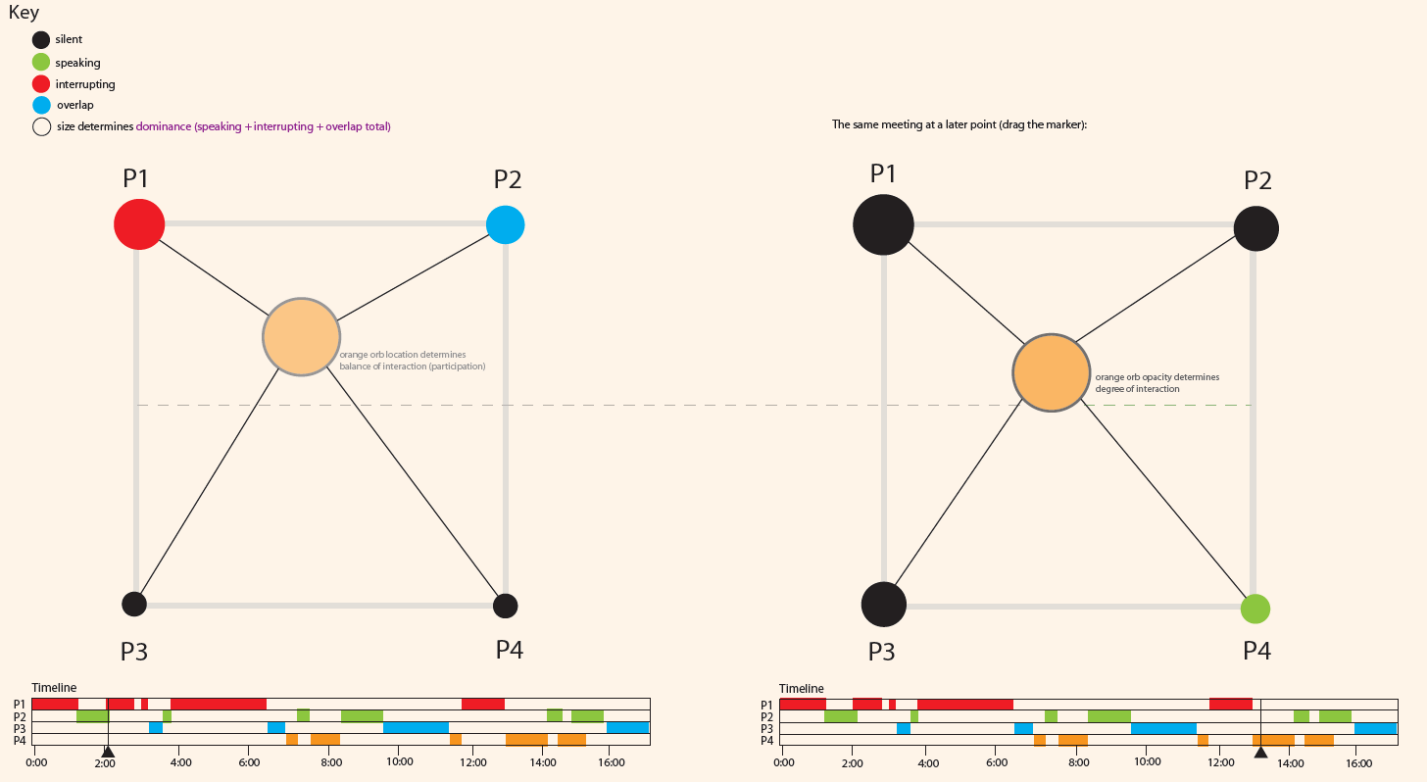


Figure 19: *The functions of mockup 1.The grid on the right is a representation of a later point on the timeline of the grid on the left.*

The data displayed in the grid and the timeline is relevant to the interaction theory selected for this mockup – speech dominance [13]. The reasons for this choice are:

- Easy to analyze, reliable speaking time, turn-taking, interruption and overlap data from the sociometric badges.
- The significance of these sociometric measurements to the dominant/non-dominant dimension of group interaction described by Bales [10].
- F2F (face-to-face), body movement and proximity data from seated individuals in an enclosed meeting space may not be as useful, due to the likeliness of the participants to be still and constantly facing each other. Thus speech variability data is more reliable in the environment selected for this study. Furthermore, the possible lack of an observer (or video system for the sociometric badge), can lead to missing out on subtle body language cues; research and measurement restricted to sound data can be more reliable in this situation.

Two types of data are proposed in this mockup –accumulative and instantaneous. The intention behind this choice is to summarize, at any given moment on the timeline, the situation up to that point and at that point (accumulative and instantaneous respectively). The bubbles vary in size and color. The size is accumulative – it represents the total dominance or, for example, the total speaking time of a participant up to the point of the marker on the timeline. The color is instantaneous – it represents the speech state (silent, speaking, interrupting, overlapping) of the participant at the selected moment.

Further inspired by MM, and also for the purpose of adding more data variables to the visualization, a central, moving circle (instantaneous data) is included. The type of data here is undetermined at this stage (described in section 6. Realization), and the purpose of the circle described is identical to that of MM. The data presented on the timeline is that of the participants' speaking time, and the color choice has no link to that of the included key and bubble color code.

The stakeholder/client reaction to mockup 1 can be summarized as follows:

Pros – simple, clear design; a great number of data sets are presented in a single visualization; useful research potential for the simultaneous presentation of accumulative and instantaneous data. This is an acceptable design for the feedback visualization.

Cons – color coding confusion (timeline vs bubbles); unclear and possibly redundant key (legend), and lacking explanation of the meaning behind size and color changes; undefined data types and methods of certain data type calculations; use of bubble size variation and a moving central circle may prove to be redundant.

With a satisfactory but imperfect first mock-up, the decision is to move onto initial user feedback and a polished mockup in the specification phase of the design process. Furthermore, data specifics and development tools/choices are to be detailed in the specification section.

5. Specification

The specification phase addresses the tools and methods used to develop the visualization. The functional specification is used to determine the ins and outs of the feedback interface and how the system will be perceived by the user; what data will be gathered from the badge, which behavioral aspects will be used and how they will be compared, as well as how the data will be presented. The experience specification determines possible user response to the system through user scenarios and storyboards, along with further research and/or user interviews.

5.1 User feedback: Mockup 1

The user feedback for mockup 1 is obtained through a short semi-structured interview following an observation of the mockup. The interview consists of the following general open-ended questions:

- What is your overall impression of this design? The purpose of this question is to get a general pros/cons overview of the design, specifically the visual aspect.
- Do you find the interaction analysis proposed by this mockup engaging? What would you like to know about your behavior? This set of questions attempts to acquire the users' perspective on the validity and the content of the selected interaction analysis.
- Is there anything you do not understand? What do you think requires change? This set of questions deals with the ambiguities and weaknesses of the design as well as with suggestions on what may be improved.

Five University of Twente students were interviewed about their impressions of mockup 1 (Appendix 1). Overall, positive comments were made about the simplicity of the presentation and its potential use for self-evaluation, regarding interaction and behavior. Of note were several remarks about the design. Users found the color coding to be a good idea, but the key's labels were seen as confusing; users were not certain about the difference between 'overlap' and 'interrupting', suggesting that this can be reduced to one variable in order to remove unnecessary redundancy and complexity. One user found the central circle to be unnecessary due to interpreting its function as identical to that of the user bubbles' size, but the rest found it to be an alternative way to look at the data – which can be useful. Three of the users found the color coding to be confusing, since the colors on the timeline do not match with the user bubble colors or the key. It is suggested that the

same color coding should be applied to the timeline and user bubbles (also remarked by the project supervisors).

5.2 Functional specification (Mockup 2)

Following stakeholder/client and user feedback, adjustments have been made to the visualization design. Key changes to the original design in mockup 1 include a clearer and simpler version of the key as well as a single color code for both the grid and the timeline. These changes were developed in order to address the most common problems described by the stakeholders and users. The new key uses only one color for any type of non-interrupting speech since overlap is self-evident when an interruption (red) is observed. Interruptions can also be seen in the timeline for quick access.

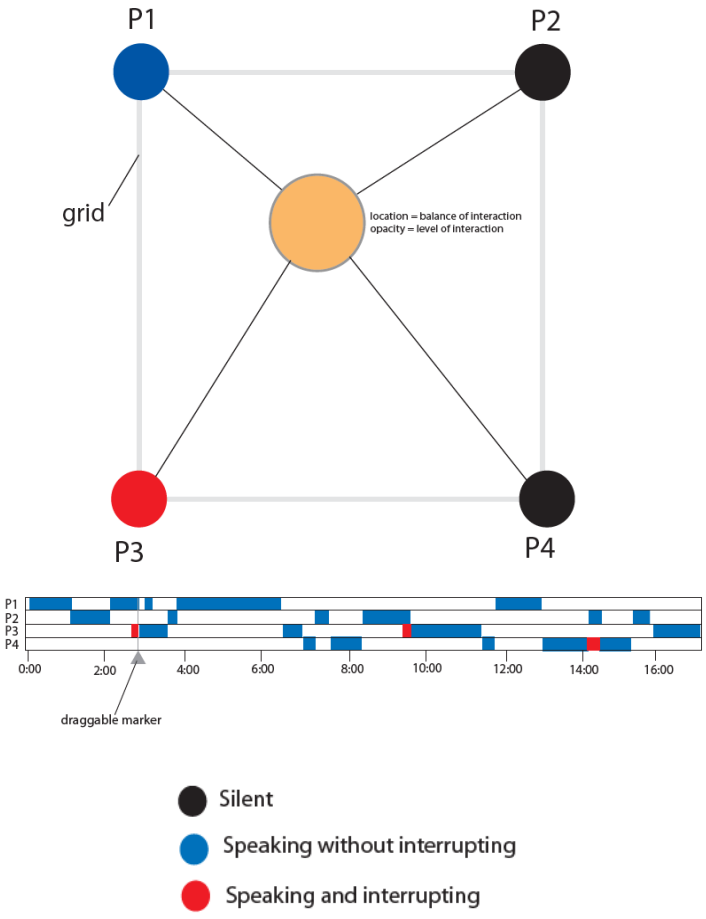


Figure 20: *Mockup 2 revision of the first mockup, based on stakeholder and user feedback.*

Final and detailed data type(s) still need to be developed for the central circle. In the meantime an alternative version for the design is proposed – one which removes the central circle entirely, and uses distance between the bubbles as a measurement of participant interactivity. This design will require further testing (feedback).

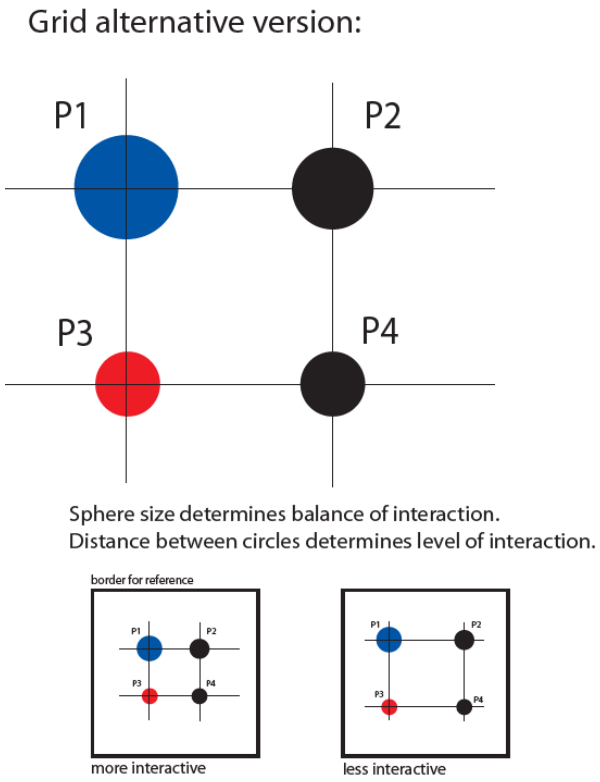


Figure 21: *Mockup 2 alternative version of the first design. The central circle is gone, and the distance between the bubbles can be used to represent a metric, e.g. the level of participant interaction.*

In order to determine which sociometric badge output data will be used, and how, it is required to look at the sociometric badge documentation, provided by Sociometric Solutions and the PCRS.

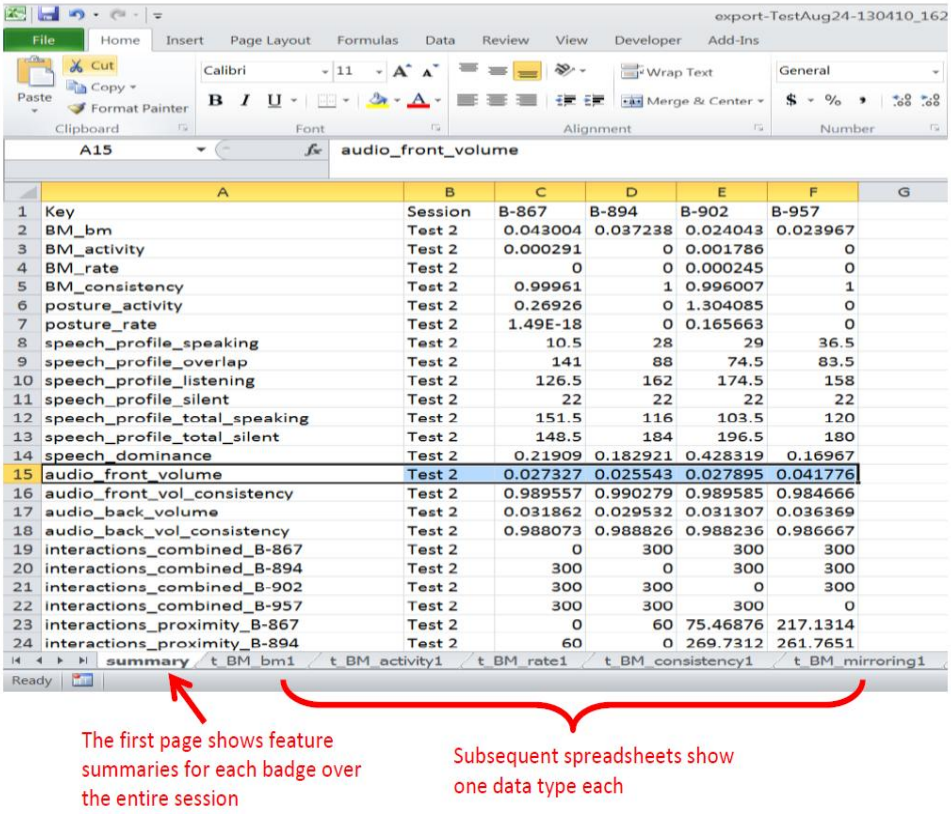
Functional specification: Data from the sociometric badge

In Alex Pentland's and Daniel Olguin-Olguin's description of the sociometric badge [14], 9 types of data are discussed: body movement activity, consistency of body movement, speech activity, consistency of speech, speaking time, face-to-face (f2f) interaction time, time in close proximity, degree (f2f) and

centrality. This project focuses on closed-door, small team meetings (ideation), as well as speech-related dominance studies; as such, the speech-related data is examined first.

1. Speaking time: minute-by-minute percentage of speaking time (captured by a microphone).
2. Speech energy: minute-by-minute speech energy captured by a microphone.
3. Consistency of speech: negatively proportional to minute-by-minute variation in speech energy. Related to mental focus and determination.

All speech measurements are captured by the sociometric badge built-in microphone. The (Sociometric Solutions) Sociometric Badge User Guide and sociometric badge sample Excel file data, both provided by the PCRS, outline these types of data on a technical level.



	A	B	C	D	E	F	G
1	Key	Session	B-867	B-894	B-902	B-957	
2	BM_bm	Test 2	0.043004	0.037238	0.024043	0.023967	
3	BM_activity	Test 2	0.000291	0	0.001786	0	
4	BM_rate	Test 2	0	0	0.000245	0	
5	BM_consistency	Test 2	0.99961	1	0.996007	1	
6	posture_activity	Test 2	0.26926	0	1.304085	0	
7	posture_rate	Test 2	1.49E-18	0	0.165663	0	
8	speech_profile_speaking	Test 2	10.5	28	29	36.5	
9	speech_profile_overlap	Test 2	141	88	74.5	83.5	
10	speech_profile_listening	Test 2	126.5	162	174.5	158	
11	speech_profile_silent	Test 2	22	22	22	22	
12	speech_profile_total_speaking	Test 2	151.5	116	103.5	120	
13	speech_profile_total_silent	Test 2	148.5	184	196.5	180	
14	speech_dominance	Test 2	0.21909	0.182921	0.428319	0.16967	
15	audio_front_volume	Test 2	0.027327	0.025543	0.027895	0.041776	
16	audio_front_vol_consistency	Test 2	0.989557	0.990279	0.989585	0.984666	
17	audio_back_volume	Test 2	0.031862	0.029532	0.031307	0.036369	
18	audio_back_vol_consistency	Test 2	0.988073	0.988826	0.988236	0.986667	
19	interactions_combined_B-867	Test 2	0	300	300	300	
20	interactions_combined_B-894	Test 2	300	0	300	300	
21	interactions_combined_B-902	Test 2	300	300	0	300	
22	interactions_combined_B-957	Test 2	300	300	300	0	
23	interactions_proximity_B-867	Test 2	0	60	75.46876	217.1314	
24	interactions_proximity_B-894	Test 2	60	0	269.7312	261.7651	

Figure 22: *The quantitative main sociometric badge data measurements.*

Quantitative data values to be considered for the feedback visualization include (as labeled in the Excel file) all the measurements beginning with 'speaking_' and 'audio_' (Note: the provided Excel datasheet file may be used during feedback in the realization and evaluation phases). Some of these overall measurements consist of additional details such as successful and unsuccessful interruptions – data

which is also applicable for the requirements of both mockups. The 'audio_' metrics are notable since they are a likely data choice for the central circle (or distance) of mockup 2.

5.2.1 Functional specification: development tools for the visualization

The feedback visualization prototype will be built from the ground up using the Processing programming language (and software) [15]. Processing is suited to constructing digital visualizations; it is developed for creating art and design through code. While Processing visualizations are often enhanced through the use of the specific libraries, e.g. graphing libraries, this project will rely on few so as to make it as personalized as possible. The timeline design aims to engage users through interaction, which will be based on mouse clicking-and-dragging or using a touch screen (desktop, tablet or smart phone).

Ultimately, data from the sociometric badges will be accessed through use of the final output file, which is currently an Excel data file. Select data from the Excel file can be saved in CSV files, which are easily accessible to Processing. This process can possibly be accelerated through direct Excel to Processing parsers. For the purpose of this project, CSV files will be used.

5.2.2 Speech dominance: speaking time and interruption

Dominance is a key dimension in social interactions [10] [13], reflective of an individual's personality, hierarchical position within a group, status and power [13]. In terms of communication and group interaction, dominance can be perceived through speech and body language. Research demonstrates that it is possible to detect speech dominance to a significant degree through an individual's speaking time and interruption.

Schmid Mast (2002) [13] concludes after multiple studies that "the duration a person talked during a face-to-face interaction was highly associated with dominance". Furthermore, Schmid Mast elaborates that "the relationship between dominance and speaking time for the sender (is) weaker than for the perceiver" [13]. This observation implies that post-interaction self-evaluation through a feedback visualization can benefit participants by allowing them to examine their own behavior from a different stance, without any real-time pressure to perform. "Speaking time does not necessarily reflect

dominance in every situation" [13], due to multiple variables, but has a strong association with dominance nonetheless, which can be beneficial for analysis using the feedback visualization. Interruption can be associated with dominance and even be a constructive function in promoting group discussion –members who were successful interrupters and capable of holding the floor when interrupted were ranked high, in a study where groups discussed euthanasia and subjects evaluated each others' performance [18]. In a similar study with 10 male and 8 female interaction dyads, subjects who scored high on personality dominance tests were observed as more frequent interrupters and more successful at holding the floor (no significant sex differences in interruption behavior) [19]. Thus, interruption can also be a useful metric in research and self-evaluation with the feedback visualization.

The speech measurements of the sociometric badge (Figure 22) conveniently consist of speaking time and overlap/interruption measures, which can be used for the purpose of speech dominance. The other key speech measures consist of volume and pitch, which have also been observed as signs of dominance during speech [21], and can also be applied to the feedback visualization at a later stage.

5.3 Experience specification

In order to determine how the feedback visualization will be perceived, two hypothetical user scenarios are created to outline the user experience.

User scenario 1

Jane, 23, studies Industrial Design at the University of Twente. Assigned to a semester-long team project, she is grouped together with 3 other students. The team is required to carry out weekly meetings where progress is planned and reviewed. Furthermore, each team member has agreed to wear a sociometric badge during meetings, for research purposes at the PCRS, with the added benefit of being able to observe their own behavior and progress post-interaction with the sociometric feedback visualization.

Prior to the meetings Jane thinks of herself as a shy and passive meeting participator. She feels that her (speech) contributions are infrequent but valuable. Following the first team meeting, Jane maintains her opinion. With a set of provided introductory instructions, Jane sits in front of a desktop computer and uses the feedback visualization to see how she and the rest of the team have performed. By scrolling through the timeline, Jane can see that at the end of the meeting each participant bubble is relatively

the same size. The team leader's bubble is the largest, and Jane's bubble is the smallest. By observing the timeline and the bubble colors, Jane sees that she has made only three interruptions throughout the entire 10 minute meeting, and has been interrupted 5 times – recovering immediately in 3 of these instances. This information is consistent with Jane's belief that her contribution is infrequent (or the least frequent). Her being able to hold the floor after 3 out of 5 interruptions could mean that her contribution was valuable or that perhaps she is perceived as more dominant than she thinks. Jane's relationship with her teammates is positive, and the team is operating as planned and desired. She sees no need to modify her participation behavior at this state.

User scenario 2

Max, 35, works with 3 acquaintances in a web development startup. The team has agreed to participate in sociometric badge testing with the University of Twente, and has already carried out 4 meetings. Using the sociometric feedback visualization, Max and the rest of the team have observed and agreed that speech-wise, Max is generally the most or second most dominant participant of the group, especially when it comes to interruption. Max is a valuable member, but often interrupts and redirects important conversations. From the 3rd meeting onwards, Max has attempted to consciously adjust his behavior and become a better listener.

Following the 5th meeting, Max analyses his current state. At a quick glance, his bubble is more often black or green, and on occasion red. His participation is currently that of a more balanced listener/speaker, with fewer interruptions. The circle in the middle is set to represent total speaking time over the past minute, gravitating towards the participants who speak the most. On 2 out of 7 occasions (i.e. during 2 out of the 7 minutes of the meeting's duration) the circle gravitates most towards Max's bubble. This is an improvement over his average of over 35% speaking time. Max and the team are satisfied with his current performance and see no reason to further influence his behavior for now. A PCRS researcher observes that from the 5th meeting onwards, contribution within the team is often spread evenly – concurrent with the team structure which is flat and democratic.

6. Realization

The realization phase is where the visualization prototype is built. Individual structural components, as well as their integration and overall function, are defined. The visual aesthetics of the visualization are finalized. The system is then tested, evaluated and fixed and/or improved accordingly. Following this phase, the final testing and evaluation can be completed.

6.1 User feedback: Mockup 2

The group of users from the first user feedback is asked to evaluate mockup 2. Each user is provided with notes of their first feedback (as a reminder) and a copy of mockup 1 and mockup 2, and is then asked the following two questions:

- How do you feel about the second, redesigned mockup? What are your observations and remarks?
- What do you think of the alternative version? Which design do you prefer?

The responses reveal a unanimous preference towards the improved use of color and key description in the redesigned mockup. Only one user prefers the alternative version, as they find the central circle to be too ambiguous. The central circle is still perceived as lacking a specific function and the users would like a clearer separation of the various data types presented.

To address the present issues, the central circle will be given a single purpose – speech dominance over the past minute, which distinguishes it as a presentation of a different data type from the user bubbles (total, or accumulative data), and also as an alternative method to observe the data – which four out of the five users perceive as useful. The data types will be entered in the key under three separate types – instantaneous, per minute and accumulative. Following these adjustments, the technical components and design can be explored.

6.2 Technical components

The components required to construct the feedback visualization prototype consist of the following:

1. The feedback visualization is built using Processing [15].
2. The timeline knob is made using the CP5 library for Processing [22]. Dragging the knob is based off a slider example with tick markers, the number of which can be adapted to the time resolution of the feedback visualization.
3. Sample CSV files are created in order to test the application's ability to load CSV data. The sociometric badge output file (Excel) can then be converted to the appropriate CSV files required for the visualization. Ultimately, the visualization is preferred to be read from Excel files directly.

6.3 Design and functional elements

As discussed in mockups 1 and 2, the aesthetic choice for the design relies on basic geometric shapes and a minimalistic arrangement, so that multiple sets of data can be viewed at once and be distinguished easily (Tufte's principle of multiple data sets in a single space [12]).

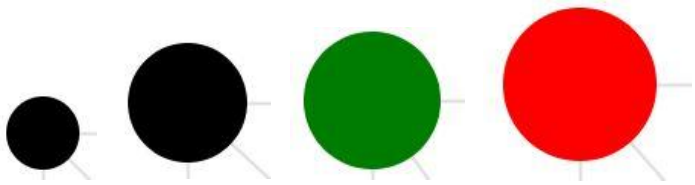


Figure 23: *A single user bubble in its various states (silent, silent, speaking without interrupting, interrupting). The bubble also varies in size (total speaking time up to point on the timeline).*

The appearance of the various changing sizes and distinguishable colors, through interaction with the visualization, follows the basic principle of encouraging the eyes to compare data [12].

Figure 24: *The central circle (left) and examples of grid lines (left and right). The grid provides structure and visual organization for the visualization, but is not the focus of the presentation and is thus built with soft, light-grey lines.*

The inclusion of an interactive timeline contributes to the visualization's ability to serve a clear purpose [12]. The visualization tells a story, where the timeline enables the user to distinguish between the beginning, middle and end of the interaction data on display.

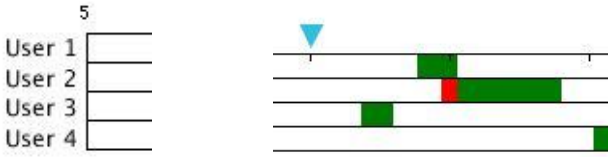


Figure 25: *Timeline fragments – left end (left) and middle (right).The number (5) above the user labels is the selected minute (time resolution used in the prototype). On the right, the timeline knob is large and distinguishable, resting over the chosen tick (minute).The color coding of the user bubbles for speech and interruption applies to the timeline. When dragged, the knob snaps onto the next or previous tick(s).*

The visualization prototype is designed with four user bubbles in mind. Theoretically, the grid can be adapted to any number of participants within the small group/team range – defined as 3 to 10 participants for the purposes for this project.

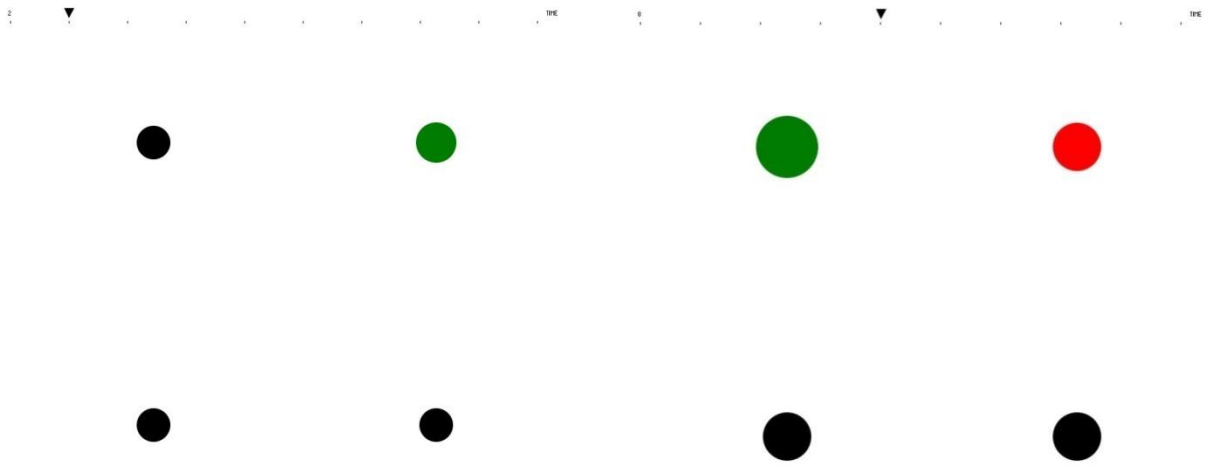


Figure 25: *Early setup of the arrangement of the four participant bubbles, along with the timeline knob. Left: early on in the meeting, right: later on.*

6.4 Integration

First, slider code from the CP5 library is adapted for use with the timeline. For the purpose of the visualization prototype, the sample meeting interaction represented is assumed to have lasted 9 minutes (0-9, i.e. 10 ticks).

```
controlP5.addSlider("time_in_minutes", 0, 9, 80, 30, 800, 15)
.setNumberOfTickMarks(10)
.setSliderMode(Slider.FLEXIBLE)
.setHandleSize(30)
.setColorTickMark(0)
.setColorLabel(0)
.setColorValue(color(0))
.setColorForeground(color(50,190,222))
.setColorBackground(color(255))
.setColorActive(color(255, 125, 0))
```

Figure 26: *The properties of the slider. Size, label, number of tick marks, and colors of the knob when static and when in use (active, i.e. the mouse pointer hovers over or clicks on the knob).*

Next, the user bubbles, grid and central circle are constructed using ellipse and line objects in Processing; size and color are defined. Sample CSV file tables are made with data for each user bubble and the central circle.

In a real scenario, data is gathered from the sociometric badge output Excel file (either the original file or one converted to CSV). A typical output file (as used at the PCRS), contains a speech-specific tab called '**t_speech_profile1**', which contains the data required for the visualization (Figure 27).

1		P1					
2		speaking	overlap	listening	silent	total_speaking	total_silent
3	########	0	0	0	1	0	1
4	########	0	0	0	1	0	1
5	########	0	0	0	1	0	1
6	########	0	0	0	1	0	1
7	########	0	0	0	1	0	1
1065	########	0	0.8	0.2	0	0.8	0.2
1066	########	0	1	0	0	1	0
1067	########	0	1	0	0	1	0
1068	########	0	1	0	0	1	0
1069	########	0	1	0	0	1	0
1070	########	0.5	0.5	0	0	1	0
1071	########	0	0.8	0.2	0	0.8	0.2
1072	########	0	0	1	0	0	1

Figure 27: *'t_speech profile1'. Each participant's speech profile consists of speaking/silent (speaking time) and overlap (which can also be used to determine interruption moments). The left-most column (########), is meant to represent every second of data gathered – 1 row = 1 second. The decimal values represent the fraction of a second during which speech has occurred. These values can be rounded-off for easier data management (for example to 1, 0 or 0.5).By having access to the total speaking times, and overlap occurrences, the application can determine the size/color of each bubble, the location of the central bubble, and the length of the colored bars of the timeline.*

For the purposes of the prototype, the timeline is a mockup, and sample CSV files (Figure 28) are used to determine the size/color of the bubbles and the coordinates of the central circle.

size	state
5	0
6	1
7	0

1	x	y
2	0	0
3	39	-39
4	7	-85

Figure 28: *CSV table (left) carrying information about the size and color (state) of the bubbles at every minute mark. A similar table (right) determines the coordinates (in pixels) of the central circle per minute.*

The central circle is based on the total speaking time over the past minute. The circle gravitates towards the area (user bubbles) with the highest percentage of speaking time. The closer the circle is to a particular bubble or general direction, the more dominant that bubble or area is (combined dominance of bubbles). To represent this visually, a set of calculations is carried out to find the 'x' and 'y' coordinates of the circle (Figure 29). For the 'x' coordinate:

- Average values Av1 and Av2, of the bubble pairs shown in the figure, are calculated. These are the averages of the bubbles' speaking time over the past minute (depending on where the knob is). T = 1 minute, i.e. the maximum speech time possible.
- At every minute mark the central circle is set in the middle of the grid. The side length of the square grid = 420 pixels; therefore the horizontal/vertical distance from the center = 210 pixels. Each average is expressed as a fraction of the total time, so as to find the horizontal location of the circle as a fraction of the total length of the x-axis. The circle needs to move from the middle and can thus go left or right. In code, relocation to the left or up is negative; it is positive in the respective opposing directions. Therefore Av1/T is assigned a negative sign.
- Summing -Av1/T and Av2/T gives the required total fraction, which is then multiplied by 420 to find the total relocation value of the circle from the 210 pixel point (center). If the final value is below 210, the circle moves to the left and vice versa.
- The above steps are repeated for the vertical axis in order to determine the 'y' coordinate. The two coordinates then determine the position of the circle at the chosen tick on the timeline.

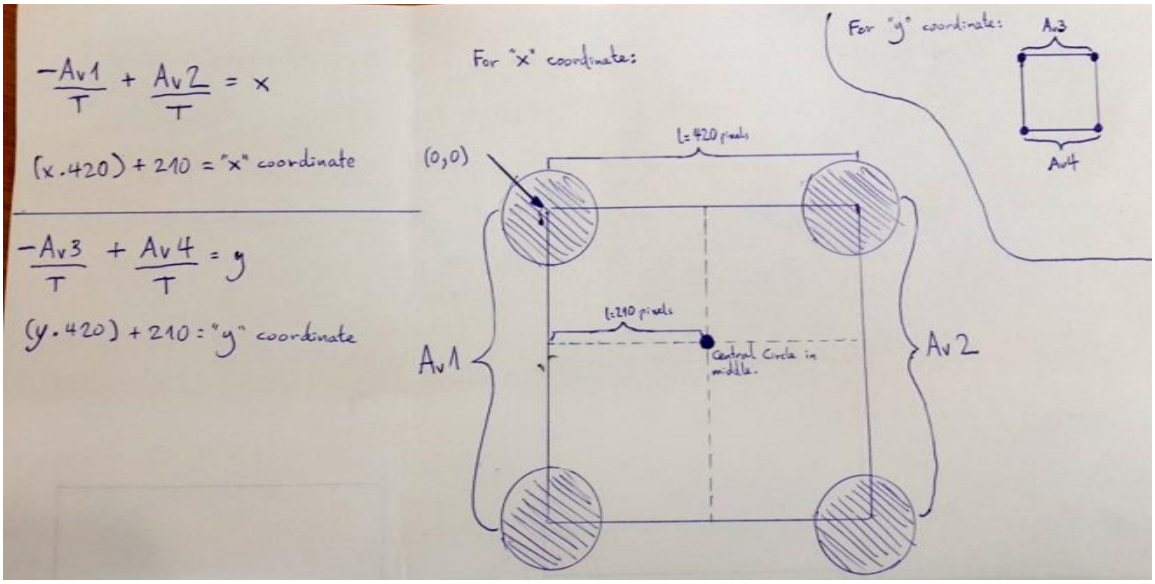


Figure 29: *Calculating the location of the central circle.*

With the user bubbles and central circle functioning accordingly with the location of knob on the timeline, testing and tweaking is done prior to the final user test.

6.4.1 Initial evaluation

The visualization functions as intended for the prototype – the knob can be dragged with a mouse or laptop touchpad, and the bubble variables and central circle location correspond to the data presented on the timeline. Some of the items may require rearrangement for a clearer visualization (the timeline is too close to the grid and bubbles), and a key/legend is still missing. User test instructions are required as the visualization may not be self-explanatory to the uninitiated.

6.4.2 Fixes and final improvements

The size and spacing of the visualization elements are adjusted to make the overall presentation clearer. A key is made for the visualization, addressing the various types of data. An introduction and instructions paper is written (Appendix 2) which is meant to explain these data types to users prior to the user test.

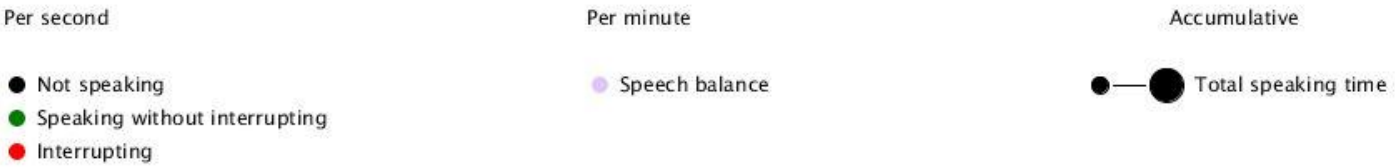


Figure 31: *The visualization key, describing the various types of data shown: instantaneous (per second), per minute and accumulative data.*

The feedback visualization prototype is now ready to be tested for the final evaluation phase of the design process.

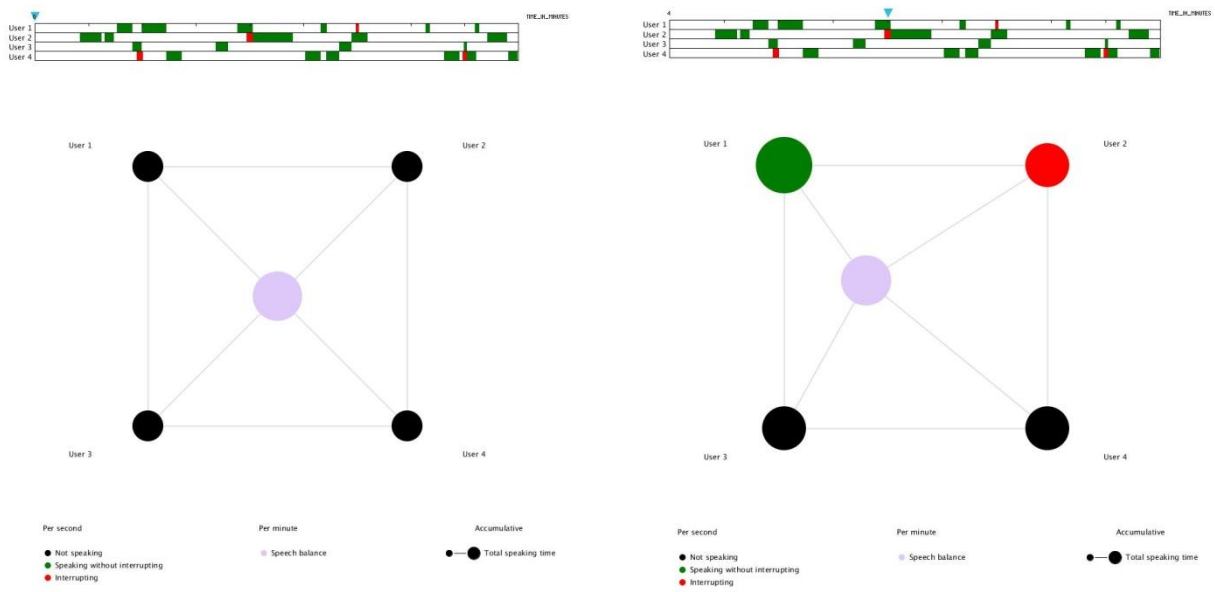


Figure 32: *The final version of the first visualization prototype. Early on in a group meeting (left) and later on in the same meeting (right).*

7. Evaluation

The final phase of the design process, the evaluation, consists of a user test with the visualization prototype, followed by an in-depth survey. User feedback is used to determine if the product provides satisfactory answers to the research questions, as well as what adjustments or improvements can be applied to the visualization in the future.

7.1 The feedback visualization

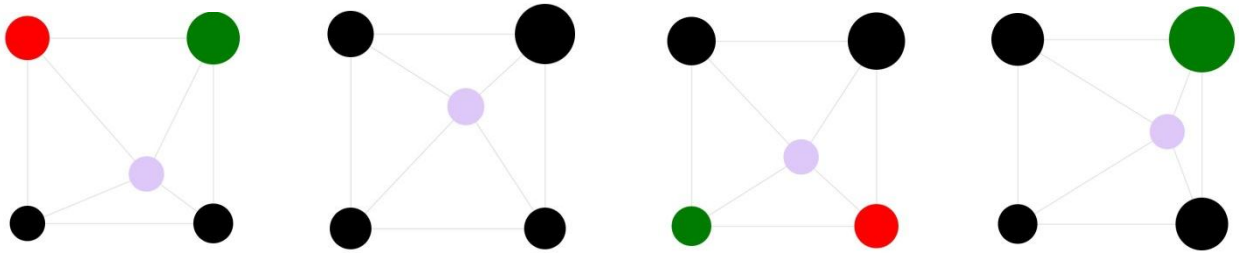


Figure 33: *Various captures from the grid section of the feedback visualization.*

The sociometric feedback visualization aims to distinguish itself with its balance of simplicity and detail, meaningfully interconnected data types, ease of use and interaction, and a design which strays away from standard statistical presentation. At a glance the visualization is primarily inspired by Meeting Mediator [5], but also incorporates other elements such as a timeline similar to those of DynaMeet [6] and ViSo (with the added feature of interaction which affects the grid section), and original elements such as the color- and size-varying user bubbles. As such the visualization is both familiar and different – more detailed than Meeting Mediator, and simpler but more focused than DynaMeet and ViSo. With the aid of a user test, the appeal of the visualization will be examined for the first time (on a small scale).

7.2 The user test

The user test is carried out with a mixed group of 20 participants – young adults who are either students or (self-) employed. A perfect user test would consist of participants who have worn sociometric badges in an enclosed, seated meeting prior to the test, after which they must evaluate their performance using their own sociometric data in the visualization. Due to the technical limitations of the prototype and

time constraints of the project, a sample, 10 minute fragment of a 4 person meeting is presented in the user test visualization. It is assumed that the user test participants will understand this context after reading through an introduction (and use instructions) provided to them prior to the test (Appendix 2). This document consists of background information, explanation of the various data types and steps on how to interact with the visualization.

In each user test instance, a user is seated in front of a computer (interaction through mouse) with the feedback visualization open and ready to use. They are provided with the introduction/instructions document, which they can read prior to or during their interaction with the visualization. After spending enough time with the document and visualization (5 to 10 minutes), the user can fill in a digital survey (Appendix 3) on the same computer. The feedback visualization remains open throughout the entire test, as certain questions in the survey require users to refer back to the visualization. After responding to the survey, the user sends their response through a 'Submit' button to a database which organizes and visualizes the response (Appendix 4). This data is used to evaluate the user test.

Note: In order to meet the project's requirements and address RQ2, the users are not explicitly told that this visualization is intended to examine speech dominance. Instead, a question in the survey is used to determine if the participants associate the visualization with speech dominance.

7.3 Evaluating the user test

The participants of the user test are young adults between the ages of 19 and 28. Fourteen (70%) of the participants are male and six (30%) female, from a mixed set of nationalities ranging from primarily Dutch and German to Canadian, Bulgarian, British, Irish, Ukrainian, Iranian and Hungarian. The participants are generally from technical, design and art backgrounds, either as students or workers. Based on this data, it is assumed that the participants are familiar with digital visualizations and computer use, both of which are key enablers for the feedback visualization.

After determining the general background of the participants, the remainder of the survey concerns the participants' experience with the feedback visualization. In order to address RQ1, "How well will a user be able to perceive a sociometric badge feedback visualization of data from an enclosed, around-the-table group meeting, as **designed** in this project?", users are asked a series of design-related questions. When asked if the users were able to distinguish between the various data types (instantaneous, per minute and accumulative), as well as the various speech states (color code), in each case 95% of the users found the data distinguishable, i.e. no seeming redundancy or confusing variables.

On the basis of multiple likert-type scale questions, all ranging from 1 to 10, users are asked to reflect on 'how well' they have perceived the visualization and data.

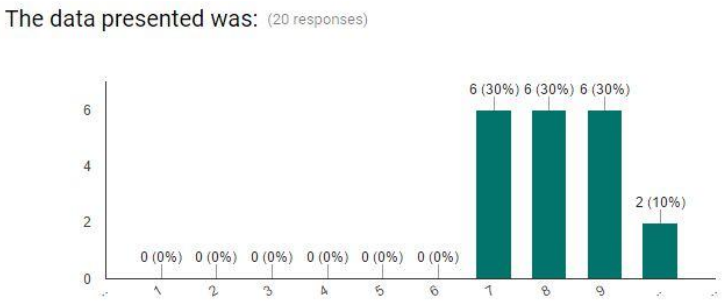


Figure 34: *From 0 (unclear) to 10 (clear) then entire user set selected 7 (30% on 6, 7 and 8 respectively) or higher regarding the data presented.*

All of the participants find the data presented to be significantly clear (7 or higher) and intuitive (6 or higher, with the majority picking 7 or 8). With an evenly spread 75% of the participants among the values 8, 9 and 10, the majority were able to asses (and understand a lot about) the total speaking time (user bubbles) and speech balance (central circle) at any instant on the timeline.

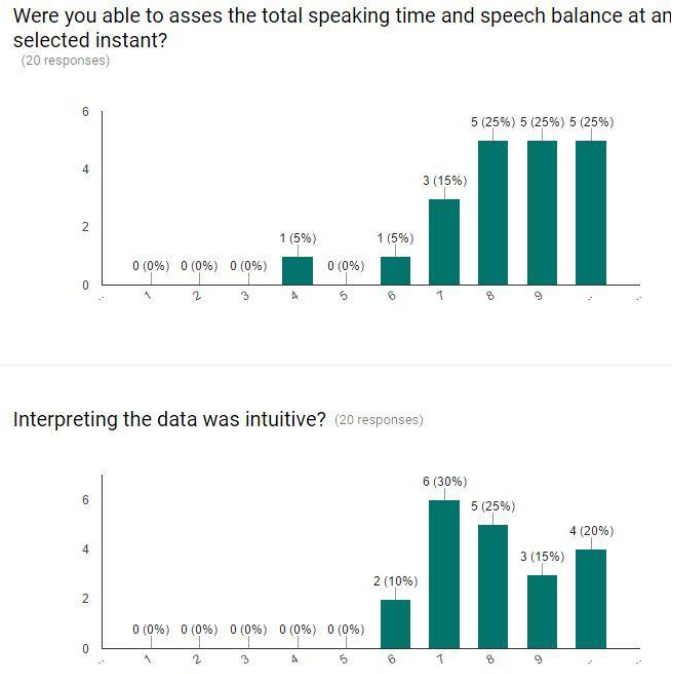


Figure 35: *Ranging from understanding nothing to understanding a lot (top) and 'unintuitive' to 'intuitive' bottom, 90% of the users find the data to be comprehensible and intuitive at 7 or higher.*

On an operational level, 60% of the users found the timeline navigation (dragging the knob) to be easy at a degree of 9 or 10; however some have picked lower values (down to 5) with a 5% outlier at 3, signifying that perhaps the timeline knob can be improved in its usability. The majority of the participants (40% at 8 and 20% at 9) feel like they gained a lot of insight into the meeting shown in the visualization.

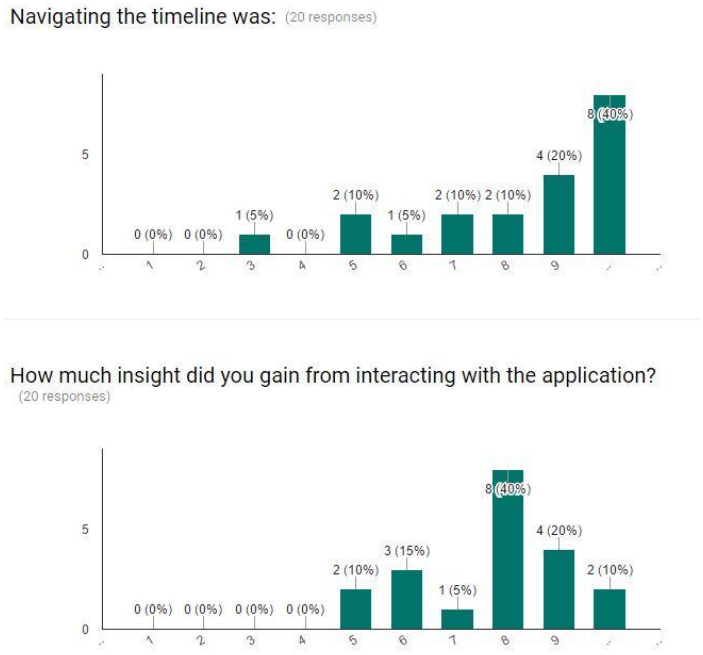


Figure 36: *Navigating the timeline (difficult to easy; top) was predominantly easy, and the majority feel like they have learned lot about the events shown in the visualization (ranging from 'I didn't learn anything' to 'I learned a lot about the meeting'; bottom).*

In order to confirm the participants' understanding of the visualization, two open questions are given where participants explain what they observe at the 3 minute mark and 6 minute mark respectively. The replies to these questions can be used to determine if the users are able to navigate the timeline precisely (go to specific points on the timeline), and if they understand how the separate elements of the visualization work and what they mean.

As seen in Figure 37, at the 3 minute mark, the visualization is fairly balanced, where User 1 has spoken the most (accumulative), everyone is silent at the moment (instantaneous) and User 1 has spoken the most over the past minute (per minute). At the 6 minute mark, the interaction is biased towards User 4,

who has spoken the most over the past minute (central circle close to User 4 bubble); User 1 is interrupting User 2 (instantaneous) and User 2 has spoken the most so far (accumulative).

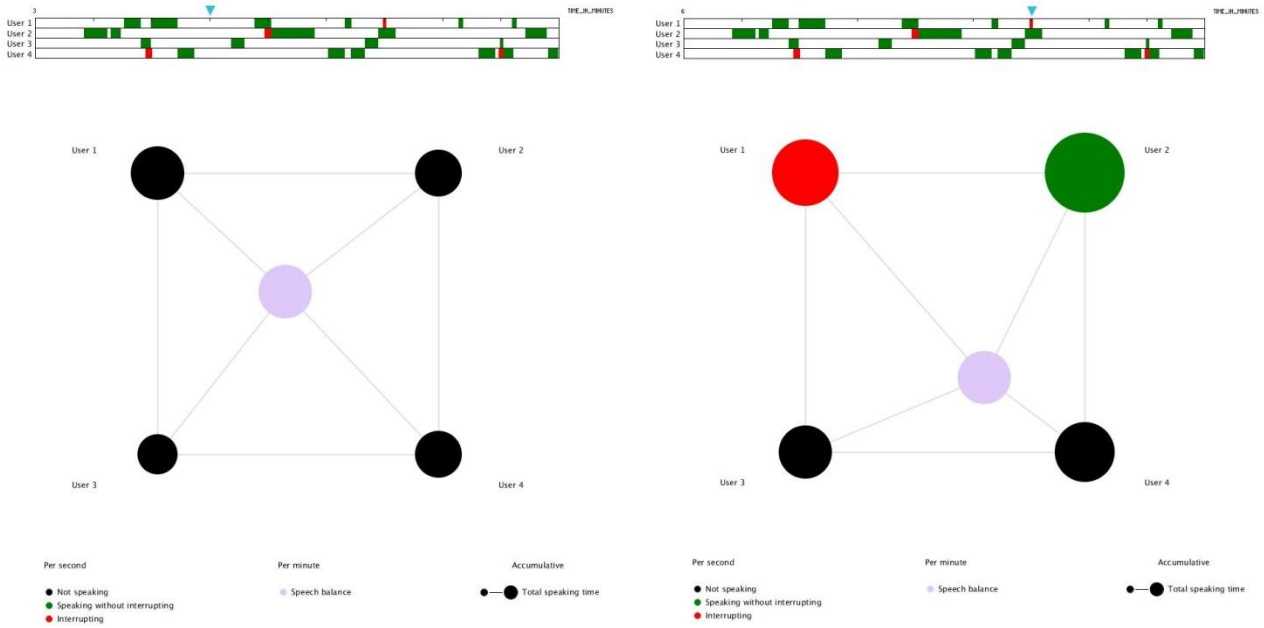


Figure 37: *The feedback visualization at the 3 minute mark (left) and 6 minute mark (right).*

Eighteen (18) out of the nineteen (19) responses given are in concordance with the description of the 3 minute mark (Appendix 3). The replies vary in detail, but generally refer to how the state is relatively neutral or how no one is speaking, for example. One participant seems to have chosen minute 2 (User 1 interrupting User 4), which perhaps may suggest that the timeline is confusing (minute 2 is the third mark on the timeline, as the time begins at 0, not 1); nonetheless, their description of minute 2 is accurate, and this response is the sole exception.

Arguably seventeen (17) of the nineteen (19) responses given seem to agree with the description of minute 6 (Appendix 3). Almost everyone explains the color coding correctly, and notes that User 4 has spoken the most over the past minute. These responses show that some users concentrate on certain types of data, with the instantaneous and accumulative data types being more noted than the per minute (central circle) data. This could suggest that the central circle needs improvement.

Following the questions about participant perception of the visualization, the participants are asked to associate the visualization with a list of interaction-themed topics, where only one choice can be made.

One of these choices is speech dominance, and thus this question can be used to test RQ2: “To what degree is the feedback visualization interpreted as relating to speech dominance?”.

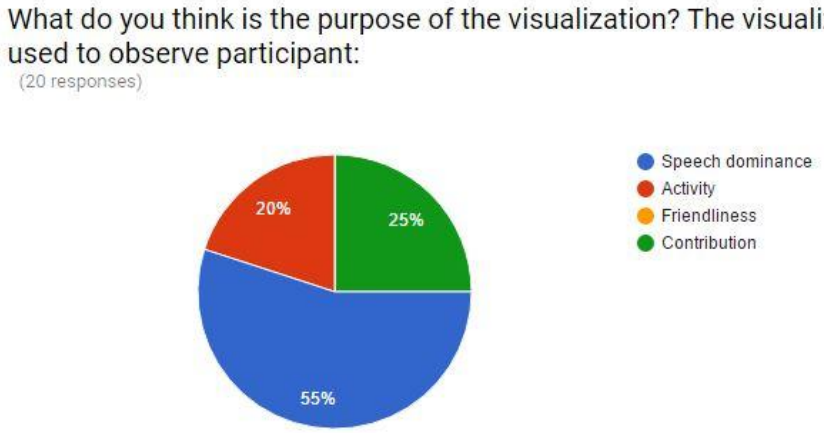


Figure 38: *More than half of the participants link the feedback visualization to speech dominance.*

55% of the participants link the visualization to speech dominance, 25% to activity and 20% to contribution. The majority of responses are in concordance with RQ2, but nonetheless a significant percentage connects the visualization to activity and contribution; either the visualization needs to represent speech dominance more effectively, or the scope of the visualization can be expanded to other topics.

95% of the participants would find the visualization useful as a self-evaluation tool (Appendix 3); this is in agreement with the chosen target group, which is expected to use the application for self-evaluation or self-observation. Reasons why reveal that participants could learn about themselves more post-interaction (a different perspective), and that the application can be used to improve the balance of meetings, i.e. not only good for the self but also the team, as well as a sign of curiosity about the behavior of others.

Finally, 11 optional remarks have been given. Criticism is given to the timeline, regarding the appearance of the minute marks and knob. One participant would prefer a more detailed legend or key in order to bypass the introduction + instructions sheet, and one would prefer an additional color for when a user is interrupted (similar to mockup 1). These can be taken into consideration regarding future work. Following the evaluation phase, conclusions can be drawn regarding the project design process and research questions.

8. Conclusion

Following the research formulation and in-depth steps of the iterative Creative Technology design process, the goal of developing a sociometric feedback visualization has been completed. This prototype is set to meet the requirements of the PCRS and potential future users, and is tasked with answering two research questions: “How well will a user be able to perceive a sociometric badge feedback visualization of data from an enclosed, around-the-table group meeting, as **designed** in this project?” (RQ1) and “To what degree is the feedback visualization interpreted as relating to speech dominance?” (RQ2). Furthermore, this feedback visualization is designed to distinguish itself from and improve upon existing applications; this is achieved by creating a design which mixes familiar and original elements, striving for a balance between complexity and scope of data visualization.

The evaluation phase reveals that the majority of the 20 participants tested perceive, comprehend and interact with the visualization prototype relatively well (on average 7 and higher out of 10 on likert-scale questions relevant to RQ1). More than 50% of the participants believe that the feedback visualization is linked to speech dominance; i.e. related to a relatively high degree (quantitatively speaking) (RQ2).

While the results of the prototype testing are satisfactory, certain design and purpose related elements may require adjustment and possibly additional features. These can be addressed by revising the CreaTe design process (or by using other methods) during future work on this project.

9. Future work

Future work to be done on this project is two-fold – design elements which were omitted from the prototype due to time limitations need to be addressed, and additions which can expand on the topic of speech dominance need to be explored.

The project still requires a quick way to load the sociometric badge output data in a timely manner, preferably through the use of an Excel parser. This will enable expanded user testing where participants can observe their own interaction in the visualization following a meeting. The timeline needs to be made fully functional, and the central circle may require a better (mathematical) method to determine its location. The visualization also requires testing on a touchpad.

Additional features which can be added to the visualization are representations of speech pitch and volume. Pitch and volume are viewed as reliable determinants of speech dominance [20] [21], and have been suggested as possible features of the central circle (by both potential users and the project supervisors).

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11. Appendix

Appendix 1: Interview notes

Interview 1 Notes (Responses)

Interviewee 1

1. Cons – colors confusing. Central circle confusing – size and central circle both represent dominance. Pros – mouse-over (but lacking key/legend clue). Pros - system adaptable for more users; length of sphere lines gives clearer impression of the dominance (Con – length not accurate).
2. Interruption data useful to possibly determine who said something more meaningful or dominant. Volume (maybe pitch) would be nice to further show signs of dominance. Also draw **connections** between interruption and volume/pitch for example.
3. Use colors for timeline and icons for bubbles. Add more key/legend info for dominance for centre circle and small bubbles, or use icons to separate their functions.

Interviewee 2

1. Con - Lacking description. Pros - Color coding useful. Size change is clear.
2. Would like to know how often and long I speak. Interesting to look at own overlap behavior. Volume, pitch and BM are interesting to know more about.
3. Insufficient explanation, include instructions/introduction if possible.

Interviewee 3

1. Pros – Size changes are a notable metric; good to be able to compare yourself to others. Cons – color coding confusing. Central circle ambiguous.
2. Would like to know more about own and others' interruption frequency.
3. Develop unified color coding for timeline and bubbles.

Interviewee 4

1. Cons – lacking text description of the details. Pros – compact presentation: multiple useful data on the screen.
2. Determining own aggressive behavior can be useful, e.g. when voice is raised (volume/pitch).

3. Add text description, point out which data set is accumulative and which one is instantaneous.

Interviewee 5

1. Pros – interaction with timeline can be engaging. Cons – accumulative and instantaneous data needs to be defined in text description or label, confusing color key.
2. It is useful to be able to analyze oneself after a meeting; real-time feedback would be too stressful. Would like to know total speech contribution.
3. Improve color key and use, simplify key if possible.

Interview 2 Notes (Responses)

Interviewee 1

1. The use of color is easier to understand. The simplified legend is a pro.
2. The improved version of the first mockup is better than the alternative version; the alternative version is too minimal and abstract.

Interviewee 2

1. Would still prefer more description, but is okay if additional explanation is provided prior to use. The key is easier to understand.
2. Prefer the improved version; the alternative version would be too animated with its changing grid size.

Interviewee 3

1. The color code improvement is a pro. Central circle needs a specified function.
2. Prefer the alternative version because it is the same concept but without the ambiguous circle.

Interviewee 4

1. The color code is improved – pro.
2. The improved version of the first design is better, as the alternative version seems to be more confusing in its functionality.

Interviewee 5

1. The key and color improvements are a pro, data types still need to be described.

2. The improved version is preferred, as the alternative version is less structured.

Appendix 2: User test introduction and instructions

Introduction

The application you are about to use is an interactive data visualization of a four person meeting (fragment) at the workplace. The data presented shows the speaking time and interruption frequency of the participants.

- Speaking time: how long a participant has spoken.
- Interruption frequency: when a participant has interrupted others.

By navigating the timeline, you can observe different points during the meeting. Three types of data are present:

- Accumulative data, or total data gathered up to the point on the timeline. The size of each user bubble represents their total speaking time, and is accumulative data.
- Instantaneous data, or data at the point (instant) on the timeline. This is moment-to-moment data (per second), and includes the color of the user bubbles (explained in the application's Key).
- Data per minute. The central bubble represents this data.

Each user's speaking time and interruption can also be seen on the timeline. The bubble in the middle 'gravitates' towards speech, and thus represents the speech distribution among all the participants – i.e. the balance of speech. The position of the middle bubble at any selected instant represents the balance of speech over the past minute.

Instructions

1. Look at the application and familiarize yourself with the elements on display. Refer to the labels and color key for more information.
2. Use the knob at the top of the timeline to navigate through the meeting. Note the various types of data on display.
3. Fill in the provided questionnaire during or after your use of the application.

Thank you for participating!

Appendix 3: User test survey

Age: *

Choose

Nationality: *

Your answer

Gender: *

- Male
- Female
- Other

Study/profession: *

Your answer

The data presented was:

	1	2	3	4	5	6	7	8	9	10	
Unclear	○	○	○	○	○	○	○	○	○	○	Clear

Were you able to distinguish the different data types (instantaneous, per minute, accumulative)?

- Yes
- No

Were you able to distinguish between not speaking, speaking without interrupting, and interrupting?

- ○ Yes
- ○ No

Were you able to asses the total speaking time and speech balance at any selected instant?

	1	2	3	4	5	6	7	8	9	10	
I didn't understand anything	○	○	○	○	○	○	○	○	○	○	I understood a lot

Interpreting the data was intuitive?

	1	2	3	4	5	6	7	8	9	10	
Unintuitive	○	○	○	○	○	○	○	○	○	○	Intuitive

Navigating the timeline was:

	1	2	3	4	5	6	7	8	9	10	
Difficult	○	○	○	○	○	○	○	○	○	○	Easy

How much insight did you gain from interacting with the application?

	1	2	3	4	5	6	7	8	9	10	
I didn't learn anything	○	○	○	○	○	○	○	○	○	○	I learned a lot about the meeting

Describe the state of the meeting at the 3 (three) minute mark.

Your answer

Describe the state of the meeting at the 6 (six) minute mark.

Your answer

What do you think is the purpose of the visualization? The visualization is used to observe participant:

- ○ Speech dominance
- ○ Activity
- ○ Friendliness
- ○ Contribution

Would you find this application useful as a self-evaluation tool?

- ○ Yes
- ○ No

Explain why.

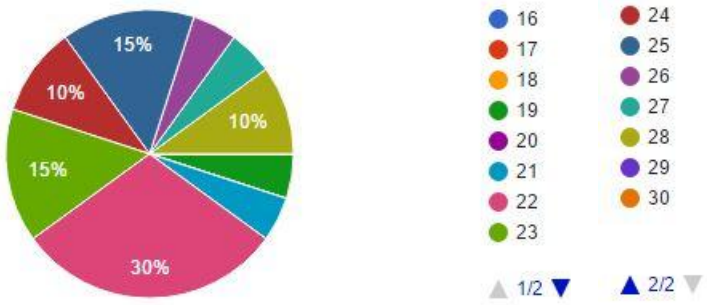
Your answer

Other comments:

Your answer

Appendix 4: User test survey responses

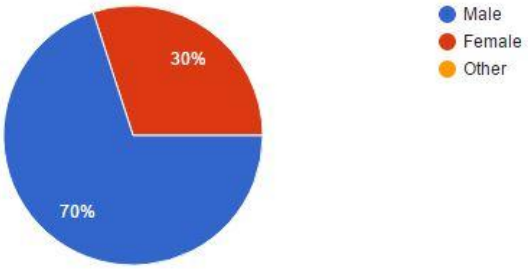
Age: (20 responses)



Nationality: (20 responses)

Dutch
Dutch
Dutch
Dutch
Dutch
Dutch
Dutch
Bulgaria
Bulgaria
German
German
german
British
Canadian
Nederlands
Irish
Ukrainian
Hungarian
Iranian
Canadian

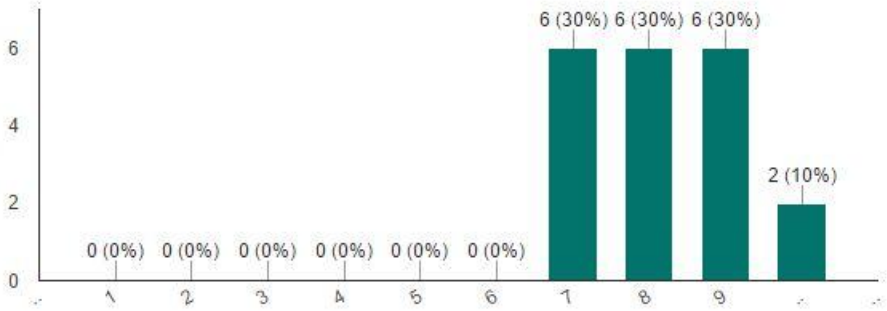
Gender (20 responses)



Study/profession: (20 responses)

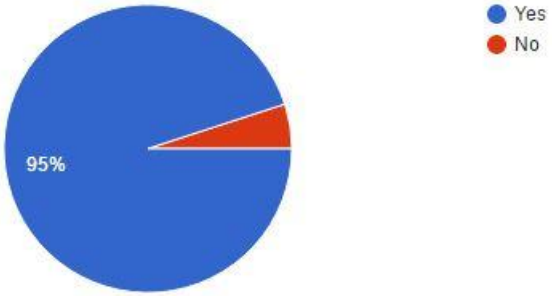
Creative Technology
Creative Technology
Creative Technology
Designer
Designer
CreaTe
MsC Communication Science / Bsc Create
EPA
Nanotechnology
Human Media Interaction
phd candidate
Student
Artist
Human Resource Management
BCs in Science
Designer
BSc Creative Technology
Sales
Industrial Design
Web design

The data presented was: (20 responses)

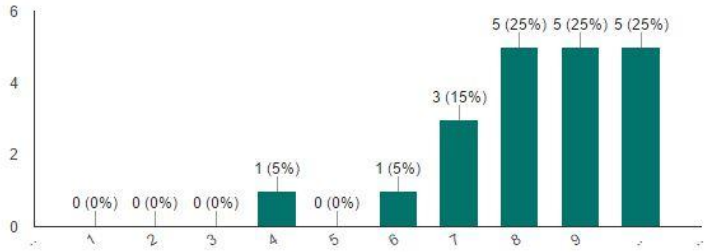


Were you able to distinguish the different data types (instantaneous, per minute, accumulative)?
(20 responses)

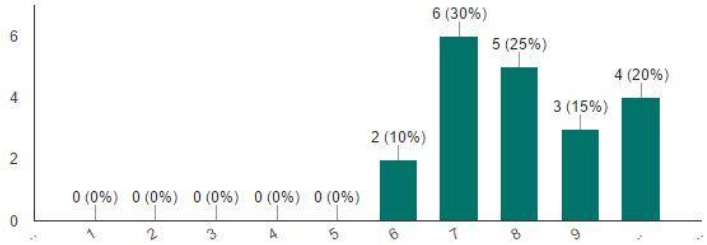
Were you able to distinguish between not speaking, speaking without interrupting, and interrupting?
(20 responses)



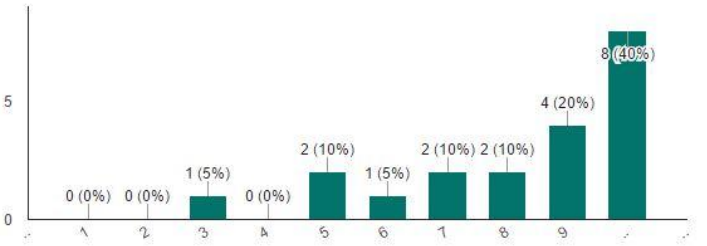
Were you able to asses the total speaking time and speech balance at an selected instant?
(20 responses)



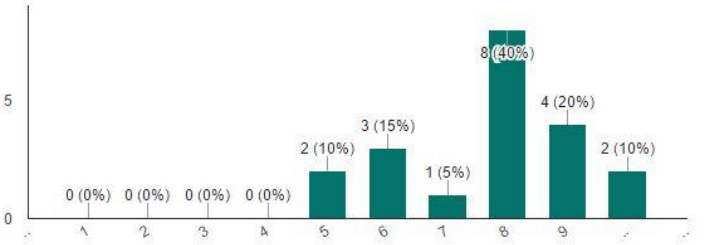
Interpreting the data was intuitive? (20 responses)



Navigating the timeline was: (20 responses)



How much insight did you gain from interacting with the application?
(20 responses)



Describe the state of the meeting at the 3 (three) minute mark. (20 responses)

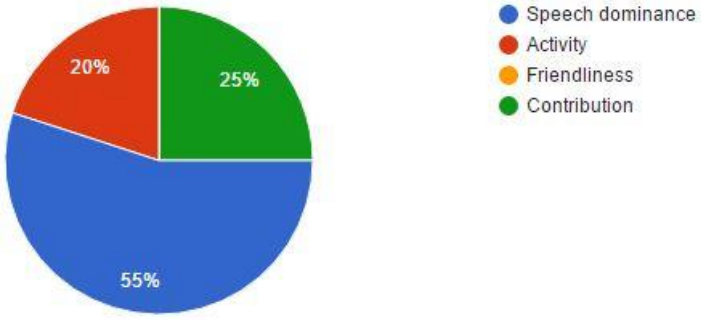
...
Everybody is silent in minute three. There might be a minute to think about something, or a switch of topic, or people are writing data down
Fairly balanced, user one and two had more to say then the other two. Maybe the opened the meeting.
All users are silent. At this moment and so far, user 1 spoke sometwhat more than the other ones. User 1 and user 2 talked, so far, somewhat more than user 3 and 4.
no one was speaking at this mark, person 1 has spoken the most up to this point, and also the last minute he has spoken the most
No one is speeking right now. and user One has spoken the most by now.
no current speaker, in the past minute, speaker 1 spoke slightly more, almost equal speaking time over the whole conversation
neutral
No one is speaking, user 1 has spoke the most up to that time (Accumaltive) and user 3 has spoke the least.
User 1 is being interrupted by User 4
neutral
No speaking but the balance is more towards user 1 because they spoke more in previous minutes
User1 has spoken the most time during this minute and in general so far. Speach balance is gravitating towards him.
Nobody is talking at the moment. User 1 spoke the most so far and User 3 spoke the least amount during the 3 minutes.
User 1 has the most total speaking time so far and there are not interruptions.
It's oh, so quiet!
User 1 spoke the most so far, nobody is speaking at that moment, the speech balance is mostly towards user 1 and a little towards user 2 but that can change in the next minute.
speech balance between 2 and 3 favoured user 1. there is no conversation at the 3 minute mark
User 1 has talked the most. No one is talking at the moment. Speech balance leans toward User 1.
No one is speaking. Relatively balanced.

Describe the state of the meeting at the 6 (six) minute mark. (20 responses)

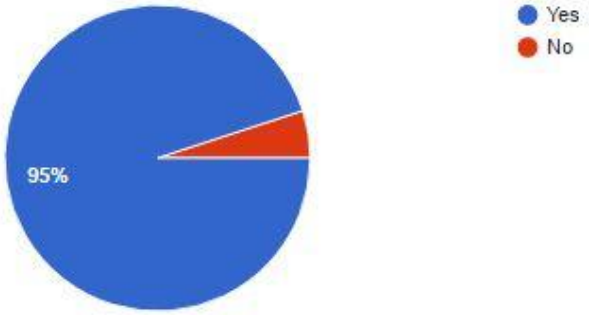
...
User 2 just explained something/ talked a lot and everybody is processing that information now.
The 'accumulative speaking time'-bubbles are bigger, so everyone has had something to say. Still person one and two have said more then the others; in the last minute at least.
User 1 is interrupting user 2 (whose turn to speak it is). The share of what was said so far is biggest for user 2. Then user 1, 4 and three are ranked respectively.
user 4 has spoken the most the last minute, now person 2 is speaking, but person one is being a dick and interrupts the speaker
User 1 is interrupting user 2.User 2 had spoken the most compared to the other users.
speaker 1 interrupting speaker 2, speaker 4 spoke most in the past minute, speaker 2 spoke most overall.
interruption from user 1
user 2 is currently speaking, but user 1 is interrupting, User 2 has spoken the most up to that minute (accumulative), and user 3 has still spoken the least
Noone is speaking
two speakers, one interrupting
Speaking with an interruption between 1 & 2, balance between 3 &4 because they spoke more in the previous minute
User2 is currently speaking and has spoken the most time on this point. User1 interrupts user2 but the speech balance is leaning towards user4
User 2 is speaking while getting interrupted by User 1. User 2 has spoken the most so far and User 3 remains the most silent one.
User 2 has the most total speaking time so far and is being interrupted by User 1 who has the second most total speaking time.
Quite a quarrel!
User 1 is interrupting user 2 as they are talking, user 2 has spoken the most so far, the speech balance for the past minute was towards user 3 and user mostly user 4.
user 4 spoke the most from minutes 5 to 6. when user 2 was speaking, he was interrupted by user 1
User 2 has talked the most, and is interrupted by User 1. Speech balance leans toward User 4.
User 1 interrupt User 2. User 4 spoke the most over last minute.

What do you think is the purpose of the visualization? The visualization is used to observe participant:

(20 responses)



Would you find this application useful as a self-evaluation tool? (20 responses)



Why?

...
It might give extra insight in meeting dynamics. Maybe people do not realize they talk or interrupt that much.
Sometimes I talk to much and I might give the impression that I don't really listen to the other person; that's bad
Some people are not aware of their behavior in discussions or conversations. Some believe they are very dominant while, in reality, they are rather silent - in comparison with their conversational partners. Others can be showed that they actually interrupt people and that they may need to adapt their behavior.
you could gain insight in how much you are interrupting people even though you might not even notice it. also you could tell how much you are speaking compared to the rest of the group.
A summary of one self that is abstracted to a common interface such as the one presented can give one significant insight in how one acts in a group. It can quite to understand once own role and to evaluate possible changes in order to optimize once own contribution.
I understand that I can observe some features of the conversation unfolding, but I don't know what the evaluation would be about; i.e. what would I be annotating/labeling/observing while using the software (that cannot also be done automatically).
It would help meetings with allowing each individual a fair shared amount of time to talk.
In terms of teamwork it can be used to interpret who the leaders of the group are, if some one is not participating, who is putting in the most effort etc. and therefore you can evaluate yourself by examining your speech activity/dominance.
It would allow me to understand how much I am contributing to discussions as well as allow me to evaluate other things such as if i am interrupting other speakers often.
Could be used in companies to assess contribution in business meetings
You could find out how you react in situations, weather your too reactive (by interrupting) or not reactive atall. See where you could improve on your presence in meetings
It visually illustrates the progress of the meeting as well as the individual performance which is useful in many case scenarios and in documenting flow of the meetings
I would like to know how often I interrupt other while they are talking. It is a bad habit and perhaps it would make more more aware.
With additional evaluation the data can be used for further clear statements about the efficiency of a team when brainstorming.
great to analyze how you behave during speech activities; in what conditions do you talk more, when would you speak without interrupting and when would you interrupt.
would be useful to know if someone was speaking too much or if someone was interrupting too much, also so that I can improve my cooperation with others
You can pin point speakers participation in a group setting. who provides the most information and the interruptions, as well as how users interact with each other
Because it gives me an idea of how an individual may react to others during a meeting, as well as overall behavior.
I can see how much I dominate conversation.

Other comments: (11 responses)

...
Good luck with your further research process!
the triangle that is supposed to mark the time could be a bit larger or more clear. also in which minute you are currently looking is not really displayed that clear
Great tool! I think with implemented automatic annotation this could be very interesting.
I would prefer a continuous timeline...
Great work! i hope to see it develop more in the future.
...
Consider adding an additional color to indicate who is being interrupted; that way it becomes clear when the speaker has finished speaking and when they have been interrupted without referencing the interrupters timeline.
If you pay close attention it becomes very clear and straightforward data visualization tool
To avoid the dependency of the manual it might be better to include a legend in the application. Very interesting research and huge potential for team observations and analysis for the purpose of improvement. Keep it up!
looks nice, would be better if the states animated in a smooth way between each other