Modelling Midstream Modulation in Medical Technology

An investigation of communication characteristics and effectiveness

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Modelling Midstream Modulation in Medical Technology

An investigation of communication characteristics and effectiveness

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For Ketchi

1. Introduction

The European Union (EU) recognizes the need for effective cooperation between science and society as a way to tackle societal issues. This effective cooperation is currently carried out in the Horizon 2020 work program (H2020). The goals of H2020 are to make certain that world-class science is developed within the EU, removing barriers to innovation and to facilitate collaboration between the public and private sectors in delivering innovation ("What is Horizon 2020?", 2018). The EU is particularly aware of the growing strain on European healthcare systems due to the growing and ageing population. The growing strain on healthcare systems will, in combination with an increasing life expectancy, lead to rising costs in healthcare. The EU started the European Initiative for Innovation and Technology (EIT) in order to empower technical experts in developing solutions to a range of societal challenges. EIT Health specifically, is focused on empowering innovation for medical purposes and incorporating socio-economic and ethical aspects (SEAs) in healthcare innovation.

The impact of SEAs within medical technology is recognized by the industry as well. For instance, KPMG reported that product development in medical technology is no longer purely within the realm of techno-science or marketing considerations. Namely, consumer preferences and data innovation are driving advances as well (Stirling & Shehata, 2015). Moreover, according to KPMG medical device manufacturers are making bigger bets on R&D initiatives, but sustained success depends on creating broader, more inclusive innovation models (Stirling & Shehata, 2015).

The growing awareness of SEAs is discussed in literature as well. Industries and knowledge institutes increasingly recognize that the socio-economic impact of science and technology needs to be taken into account in research and development (R&D) trajectories (Conley, 2011; Fisher, Mahajan, & Mitcham, 2006; Stirling & Shehata, 2015). A growing insight is that "an engineering design can be made more sustainable by holistically considering the social, environmental, and economic dimensions of the system" (McTiernan, Polagye, Fisher, & Jenkins, 2016, p.1). Nevertheless, the actual work space of scientist and engineers has not been recognized enough as an environment to incorporate SEAs (Conley, 2011; Fisher et al., 2006). Therefore, a more intensive incorporation is needed as well as methods to organize innovation.

Socio-Technical Integration Research (STIR) is the social scientific field, which focusses on the inclusivity of innovation and the impact of SEAs on R&D agendas. The term Socio-technical integration is defined as "any process by which technical experts account for the societal dimensions of their work as an integral part of this work" (Fisher & Maricle, 2014, p.3). In the daily work space of scientists, also referred to as the midstream, STIR finds its application through a method called midstream modulation (MM).

Originally, MM is a systematic, collaborative process of identifying and governing SEAs in R&D facilities (Flipse, van der Sanden, van Dam, Oude Vrielink, & Stragier, 2015). As said by Arie Rip in 2006, the term modulation refers to the subtle changes that governance actors can attempt to make to what is already going on (Fisher et al., 2006). Modulations can be distinguished on three levels, being *de facto*, *reflexive* and *deliberate*. De facto modulations

can be numerous technical, economic, ethical or even social factors of the work of a technical expert. Reflexive modulations occur when the expert has a heightened awareness of these de facto modulators. Deliberate modulations are intentional actions taken by technical experts in order to shape professional decisions (Flipse, van der Sanden, & Osseweijer, 2013). In practice, these three analytically distinct modulations might iterate and even overlap (McTiernan et al., 2016).
Recently, MM has been applied in industrial innovation processes in addition to research projects at universities. This is an important step, since a significant part of all innovations are made in a corporate-industrial environment. Results of MM studies, conducted in corporate settings, show improvement in Key Performance Indicators (KPIs) such as budget aspects, consumer insight and communication (Flipse et al., 2013). Hence, the impact of MM is deeper than heightened awareness of SEAs alone. This development goes hand in hand with a recent outcome that STIR and MM can be institutionalized in industrial R&D processes by having a technical expert, instead of a social scientist, implement STIR and MM their research projects (Fisher, Jenkins, McTiernan, & Polagye, 2016).

Previous studies demonstrate that MM is effective in a variety of technological practices, such as nanotechnology and mechanical engineering. For example, participating experts show modulations in how they communicate about their work, collaborate with others, make (technical) decisions and organize R&D trajectories. The nature and the context of some of the modulations identified in prior studies are discussed in section 2.2. A more elaborate discussion of modulations found in literature is found in section 5.1. Despite of the variety of contexts and the growing number of MM studies, it is currently still not understood *how* MM actually works, from a communication perspective. There are no studies found that model or even explore the dynamics and characteristics of MM communication. The problem of this particular study is therefore formulized as the lack of understanding MM communication.

Given the research problem, the primary goal of this study is to investigate the characteristics and dynamics of MM communication as well as to capture the outcomes of this investigation in a model which hypothesizes these characteristics and dynamics. Formulating this goal is important for the development of embedded humanism (e.g. training) and therefore MM as a method of innovation support and management as well. The primary research goal is not bound to a specific context. For this particular study nevertheless, the context is defined by a corporate design team developing medical device technology. The context caters to the aforementioned growing attention for the incorporation of SEAs within medical device technology as well as the increasing demand for inclusive design methods. In order to thoroughly understand and model MM communication, we need to be able to observe modulations. Therefore, the conditional goal of this research is to validate MM within the field of medical device technology. It is important to note that neither the primary goal or the conditional goal have been reached in previous studies thus far.

1.1 Research questions

The conditional research goal is to validate MM within the field of medical device technology. We need show that participating technical experts undergo similar effects, modulations, as found in literature. Therefore, the conditional research question is: *How do the modulations found in this study, if any, compare to modulations found in earlier midstream modulation studies?*
In order to answer this question, we would first have to identify modulations. If there are any modulations, the next step is to compare their nature, being de facto, reflexive or deliberate, to modulations reported in literature.

Presuming that MM can be validated in the field of medical device technology we can work towards answering the primary research question: *What are the characteristics of the communication that takes place between embedded humanists and technical experts during midstream modulation?*

As mentioned before, the goal is to capture the findings on the characteristics and dynamics of MM communication in a model. The reason for building a model is the possibility it grants us to summarize and focus the elaborate and probably wordy descriptions of communication segments in a visually clear and appealing manner, which allows researchers and EHs to communicate about the MM process easier and more effectively in training situations e.g. There are two main and most elementary requirements that we choose to focus on in designing a clear and usable model. The first requirement is to systematically describe communication between EHs and technical experts so that it can be reviewed by other researchers. Arguably, this demand calls for a “common language” between (science) communication researchers. The essay ‘Communication theory as a field’ by Robert T. Craig (1999) offers the approach that is applied in this study. In his essay, Craig presents a meta-model with the goal of establishing better coherence between seven of the most recognized communication theories. The overarching quality of Craig’s meta-model, which is discussed further in section 2.1, is the exact reason for choosing it as a building block for the MM communication model.
The second requirement of the model is to study to describe if and how MM communication changes over time, per participant and per the particular *issue* that is discussed. Possibly, changes in communication can be attributed to time, the particular expert, the issues that they face or even to a combination of these parameters. This requirement implies the need for a level of pliability of data that has not been seen in related studies. We need to be able to compare communication segments per participant, issue, relevant communication theories and all this in relation to a time-parameter. In order to accomplish this level of pliability, this study introduces a new and experimental database structure that allows for data to be (systematically) analyzed and classified. Section 3.3 will cover a detailed description of the data acquisition method and the database structure that follows from it.

2. Theoretical Framework

2.1 Analysis of communication

In 1999 Robert T. Craig published an essay called 'Communication theory as a field' in which he presents a reconstruction of communication theory. Craig argues that there is a lack of coherence in the field of communication theory. Unlike some of his predecessors and peers, he does not call for a grand unified communication theory. Instead, he suggests communication theory could become a field of dialogical-dialectical coherence with seven different, yet equally important, traditions of communication theory. According to Craig, "each tradition is identified by its characteristic definition of communication and its associated definition of communication problems, meta-discursive vocabulary, taken-for-granted meta-discursive commonplaces that make the tradition plausible, and meta-discursive commonplaces that the tradition interestingly reinterprets or challenges", as seen in table 1 (Craig, 1999, p. 132).

	Rhetorical	Semiotic	Phenomenological	Cybernetic	Sociopsychological	Sociocultural	Critical
Communication theorized as:	The practical art of discourse	Intersubjective mediation by signs	Experience of otherness; dialogue	Information processing	Expression, interaction, & influence	(Re)production of social order	Discursive reflection
Problems of communication theorized as:	Social exigency requiring collective deliberation and judgment	Misunderstanding or gap between subjective viewpoints	Absence of, or failure to sustain, authentic human relationship	Noise; overload; underload; a malfuction or "bug" in a system	Situation requiring manipulation of causes of behavior to achieve specified outcomes	Conflict; alienation; misalignment; failure of coordination	Hegemonic ideology; systematically distorted speech situation
Metadiscursive vocabulary such as:	Art, method, communicator, audience, strategy, commonplace, logic, emotion	Sign, symbol, icon, index, meaning, referent, code, language, medium, (mis)understanding	Experience, self & other, dialogue, genuineness, supportiveness, openness	Source, receiver, signal, information, noise, feedback, redundancy, network, function	Behavior, variable, effect, personality, emotion, perception, cognition, attitude, interaction	Society, structure, practice, ritual, rule, socialization, culture, identity, coconstruction	Ideology, dialectic, oppression, consciousness-raising, resistance, emancipation
Plausible when appeals to metadiscursive commonplaces such as:	Power of words; value of informed judgment; improvability of practice	Understanding requires common language; omnipresent danger of miscommunication	All need human contact, should treat others as persons, respect differences, seek common ground	Identity of mind and brain; value of information and logic; complex systems can be unpredictable	Communication reflects personality; beliefs & feelings bias judgments; people in groups affect one another	The individual is a product of society; every society has a distinct culture; social actions have unintended effects	Self-perpetuation of power & wealth; values of freedom, equality & reason; discussion produces awareness, insight
Interesting when challenges metadiscursive commonplaces such as:	Mere words are not actions; appearance is not reality; style is not substance; opinion is not truth	Words have correct meanings & stand for thoughts; codes & media are neutral channels	Communication is skill; the word is not the thing; facts are objective and values subjective	Humans and machines differ; emotion is not logical; linear order of cause & effect	Humans are rational beings; we know our own minds; we know what we see	Individual agency & responsibility; absolute identity of self; naturalness of the social order	Naturalness & rationality of traditional social order; objectivity of science & technology

Table 1: Seven traditions of Communication Theory

Although Craig considers all traditions to be equally important, some have quite an opposing view on communication. Craig embraces these differences by making space, topoi, for argumentation across traditions. Craig says, "the purpose of Table 2 is to indicate distinctive critical objections that each tradition would typically raise against each tradition's typical way of analyzing communication practices" (Craig, 1999, p. 132).

	Rhetorical	Semiotic	Phenomenological	Cybernetic	Sociopsychological	Sociocultural	Critical
Against rhetoric	The art of rhetoric can be learned only by practice; theory merely distracts	We do not use signs; rather they use us	Strategic communication is inherently inauthentic & often counterproductive	Intervention in complex systems involves technical problems rhetoric fails to grasp	Rhetoric lacks good empirical evidence that its persuasive techniques actually work as intended	Rhetorical theory is culture bound & overemphasizes individual agency vs. social structure	Rhetoric reflects traditionalist, instrumentalist, & individualist ideologies
Against semiotics	All use of signs is rhetorical	Langue is a fiction; meaning & intersubjectivity are indeterminate	Langue-parole & signifier-signified are false distinctions. Languaging constitutes world	"Meaning" consists of functional relationships within dynamic information systems	Semiotics fails to explain factors that influence the production & interpretation of messages	Sign systems aren't autonomous; they exist only in the shared practices of actual communities	Meaning is not fixed by a code; it is a site of social conflict
Against phenomenology	Authenticity is a dangerous myth; good communication must be artful, hence strategic	Self & other are semiotically determined subject positions & exist only in/as signs	Other's experience is not experienced directly but only as constituted in ego's consciousness	Phenomenological "experience" must occur in the brain as information processing	Phenomenological introspection falsely assumes self-awareness of cognitive processes	Intersubjectivity is produced by social processes that phenomenology fails to explain	Individual consciousness is socially constituted, thus ideologically distorted
Against cybernetics	Practical reason cannot (or should not) be reduced to formal calculation	Functionalist explanations ignore subtleties of sign systems	Functionalism fails to explain meaning as embodied, conscious experience	The observer must be included in the system, rendering it indeterminate	Cybernetics is too rationalistic; e.g., it underestimates the role of emotion	Cybernetic models fail to explain how meaning emerges in social interaction	Cybernetics reflects the dominance of instrumental reason
Against sociopsychology	Effects are situational and cannot be precisely predicted	Sociopsychological "effects" are internal properties of sign systems	The subject-object dichotomy of sociopsychology must be transcended	Communication involves circular causation, not linear causation	Sociopsychological theories have limited predictive power, even in laboratory	Sociopsychological "laws" are culture bound & biased by individualism	Sociopsychology reflects ideologies of individualism, instrumentalism
Against sociocultural theory	Sociocultural rules, etc., are contexts & resources for rhetorical discourse	Sociocultural rules, etc., are all systems of signs	The social life-world has a phenomenological foundation	The functional organization of any social system can be modeled formally	Sociocultural theory is vague, untestable, ignores psychological processes that underlie all social order	Sociocultural order is particular & locally negotiated but theory must be abstract & general	Sociocultural theory privileges consensus over conflict & change
Against critical theory	Practical reason is based in particular situations, not universal principles	There is nothing outside the text	Critique is immanent in every authentic encounter with tradition	Self-organizing systems models account for social conflict & change	Critical theory confuses facts & values, imposes a dogmatic ideology	Critical theory imposes an interpretive frame, fails to appreciate local meanings	Critical theory is elitist & without real influence on social change

Table 2: Topoi for argumentation across traditions

Craig's essay is valuable to this study for its meta-model of seven meta-discursive traditions and their respective vocabularies. Also, these traditions and their vocabularies are well-known and proven concepts in both communication sciences and science communication. The model provides a theoretical grid and a "common language" to describe MM communication. The first condition of the primary research question is met with a successful application of Craig's meta-model.
As this study is the very first of its kind, the choice for Craig's rather general grid is a conscious one. The expectation is that Craig's meta-model will enable us to successfully describe and model MM communication with sufficient level of detail. Also, a more detailed theoretical grid is not preferred at this stage of the research because of limited time available. However, the use of a more detailed grid is not excluded from future research if the application of Craig's model turns out to be insufficient.

The second condition of the primary research question introduces the parameters *time, participant and issue* and appears to have similarities with the field of discourse analysis (DA). "Discourse analysis considers how language, both spoken and written, enacts social and cultural perspectives and identities" (Gee, 2011, p. 1). DA states that communication is just one of the many functions that language serves in our lives. An 'ideal' DA, as Gee calls it, is about asking questions about how language, at a given time and place, is used to engage in particular building tasks, which is not within the scope of this particular research (Gee, 2011). The most important point to take away from studying the definition of DA is that analyzing how language enacts sociocultural perspectives or identities, at a given time and place, is not the same as analyzing if and how communication changes over time per participant or per issue.

2.2 The Embedded Humanist

Previous studies have used different definition of an EH. Being a novice EH myself, it is important to take in all of these definitions for they provide practical ideas and boundary conditions of the role that EHs fulfill in MM trajectories.
Daan Schuurbiers and Erik Fisher define the EH as an individual who interacts with researchers to "identify and assess opportunities for influencing research decisions in accordance with societal concerns" (Schuurbiers & Fisher, 2009, p. 425).
Sharon Conley refers to engagement agents as "a new generation of researchers that possess the knowledge and capacities to forge 'novel linkages' between the oftentimes disparate terrains of science, politics, and policy" (Conley, 2011, p. 720). Moreover, she suggests that "the direct experience with laboratory practices, afforded by sustained integration work, can develop into a type of competence that allows engagement agents to follow, critique, and contribute to social and material practices on multiple activity levels, to the extent that the engagement agents themselves can potentially interact on a contributory basis" (Conley, 2011, p. 720).
More recent papers show a moderate shift from the heavy societal and political connotation. In 2013, Steven Flipse, Maarten van der Sanden and Patricia Osseweijer defined the EH as somebody who "interacts regularly with researchers at their laboratories […] to incrementally 'broaden' research decisions with social and ethical considerations" (Flipse et al., 2013, p. 186).

2.3 The context and nature of modulations

As mentioned before, MM has been applied in a variety of technological practices, such as nanotechnology, molecular biology, food technology and mechanical engineering. The setting in which MM has been applied so far, differs from academic to corporate. The professional context of the MM studies is made up by the technical expert, the particular technological practices and the setting in which these practices take place. The following section gives a brief overview of the professional contexts and the nature of the modulations of previous MM studies. The differences and similarities between these studies and the research that is covered in this paper are discussed in chapter 5.

Erik Fisher's 2007 ethnographic intervention in an academic nanotechnology research group showed several modulations based on interactions with the participating engineer. Although Fisher does not explicitly refer to the changes in the engineer's governance as modulations, we can recognize reflexive and deliberate modulations in the considerations and the outcomes of the engineer's decision-making concerning self-reflection, the shaping of research agendas as well as more technical issues as the use of materials and catalysts (Fisher, 2007).
In 2011 Daan Schuurbiers applied MM in order to investigate the potential for interdisciplinary collaborations with the goal to enhance critical reflection of scientists and engineers. The participating experts were all PhD candidates in the field of molecular biology and nanotechnology working at either TU Delft or at ASU in Tempe, Arizona. Interestingly, and contrary to their initial beliefs, the participants came to acknowledge that broadening their work with SEAs has permeated their research. According to Schuurbiers, "MM was found to engender fruitful and meaningful collaborations between social and natural scientists, encouraging second-order reflective learning while respecting the lived morality of research practitioners" (Schuurbiers, 2011, p. 786).

In 2013, Steven Flipse et al. conducted an MM study in the field of food technology. The researchers elaborate on several modulations identified in the work of one of the participating technical experts. The expert is a project leader of a group who conducts industrial R&D. Simply said, he designs a production process for a food product made from side streams of biofuels production based. Despite the very technical nature of the expert's work, the modulations found primarily entail communication and cooperation during technology development (Flipse et al., 2013).
In 2016, a group of STIR researchers, among which Erik Fisher, wrote a paper that describes how STIR, through MM, is applied onto a future visioning exercise for tidal energy systems. The study is very different to the other studies mentioned in this section since "the STIRer was not a typical embedded humanist, but rather a trained engineer and a graduate student on the research team"(McTiernan et al., 2016, p. 1). Initially, the future visioning was not considered during the MM decision protocol. This, and the assumption that the conversations should be rigid and formal, lead to frustrations among the participating team members. When MM was applied in a more collaborative mode and was no longer kept separate from the future visioning, the visioning expanded and more considerations were included. The participating technical expert reflected that "the insights gained through MM will impact his future approach to interdisciplinary research" (McTiernan et al., 2016, p. 8).

2.4 STIR and HTA

Literature on RRI and the governance of innovation is widely available (Stilgoe et al, 2013; Van Opheusden 2014 i.e.). On the other hand, not much is published on RRI within the field of medical device technology specifically. There is, however, ample research conducted in the field of Health Technology Assessment (HTA). "HTA is a field of applied research that seeks to gather and synthesize the "best available evidence" on the costs, efficacy, and safety of health technology" (Lehoux & Blume, 2000, p.1083). As a matter of fact, quite recently, a number of HTA publications have been explicitly calling for better integration of organizational, clinical, societal and ethical considerations into the research, design, and development of medical innovations (Demers-Payette, Lehoux, & Daudelin, 2016). Despite of the common goal of integrating SEAs into the design and development of medical innovations, there is one big theoretical difference between HTA and this STIR study. Where HTA emphasizes on upstream activities, STIR is explicitly focused on midstream activities first and, moreover, requires the expert to interact with the EH.

3. Methodology

The research plan is to setup a case study in which MM is applied in daily activities of technical experts. The audio from the communication that takes place during the MM sessions is recorded. The recordings are used to validate MM, by observing modulations, as well as to systematically describe and model communication between EHs and technical experts, based on the seven communication traditions.

3.1 Research preparation

In order to be able to answer the research questions, some training as an EH was required. In preparation of this study, I was able to join the STIR Workshop 7 (Cardiff, May 2016) where Erik Fisher provided novice EHs with the basic training in MM. My academic background is in Mechanical Engineering, in which I hold a bachelor's degree from TU Delft. As a master's student of Science Communication at the same university, my technical education has been in the field of Medical Engineering within the master track *Medical Safety and Medical Instruments*.
I have conducted a pilot MM study consisting of eight sessions, with a total length of 7.5 hours. The sole participant was a graduate student in *Medisign* at TU Delft. She held a bachelor's degree in Industrial Design and followed a minor in Medicine. The participant's final design assignment was completed at a Dutch R&D institute that is embedded in an academic hospital. The assignment revolved around in-situ cleaning of a laparoscopic device.

3.2 Case study description

The case study is set around an international and intercultural collaboration between three companies with a total of four participants. The initial goal of the collaboration was to either develop a minimum viable product that was supported by clinicians (end-users) and attract investors or to work towards an exit strategy. The clinical application of the product was in the field of minimal invasive surgery. The participants, as well as the companies, are anonymized for privacy reasons.

Company A is a scale-up in medical technology and is located in the Netherlands. P1 (male) is Dutch and has a PhD in Biomechanical Engineering. He is a co-founder and the Director of Operations and Technology of the company. P1 is an expert in designing and developing technical concepts for medical application and has a lot of experience in filing patents. Initially, the primarily role of P1 was that of advisor and driver of the project.
P2 (male) is Dutch as well and holds a master's degree in Biomedical Engineering. He is the other co-founder, as well as the Director of Business of Company A. P2's main tasks revolve around planning, budgeting and compliance with the Medical Device Directive (MDD) for CE certification.

Company B traditionally is a software development firm that is trying to get a foothold in the field of medical device technology. The company is located in Iceland where P3 works as Lead engineer. P3 (male) is Icelandic and holds a master's degree in Biomechanical Engineering. P3 has studied in the Netherlands but moved back to his home country after he graduated. P3's task in the project is to design and validate new technology.

Company C is a company for medical and biomechanical design and consultancy. The founder, P4, is an American who lives and works in the Netherlands. He holds a PhD in Medical Design & Product Development and his field of expertise is designing compliant mechanical systems as well as sales-related interactions with end-users.

During the MM sessions, it became obvious that some team members have very different perceptions of their personal role, as well as the direction the R&D should take and of how funds should be spent. The difference in perspectives leads to enormous tension and conflict between company A and B on one side and company C on the other. Eventually, Company A and B split with Company C due to the tension and conflicts. The MM trajectory has brought forward a number of modulations that influenced the progress of the project as well as personal development of individual project members.

3.3 Research design

Initially, the intention was to have a total of 8 individual meetings per participant. The goal was to meet on a weekly basis. In practice however, this was not possible to achieve due to the conflicts within amongst the project members. In fact, the MM trajectory took a lot longer than the estimated eight weeks. The duration of a typical meeting was set to be 45 minutes at most. In practice, many sessions turned out to be either shorter or longer. The plan was to have as many face-to-face sessions as possible. However, because of time reasons, some of the sessions with P2 and P4 were conducted online via Skype or Google Hangout. Naturally, having face-to-face sessions with P3 was not possible due to distance. Therefore, all sessions with P3 were conducted via Skype calls. The audio of the sessions was recorded with permission of the participants.

3.3.1 Introducing the decision protocol

The decision protocol for MM, which was first introduced by Erik Fisher in 2007, was considered in structuring the interactions between the EH and the technical experts. Fisher defines a decision as a "commitment to a course of actions" in which he distinguishes four stages: *Opportunity, Considerations, Outcomes and Alternatives* (Fisher, 2007, p. 158). By iteratively projecting research decisions, challenges or values onto the protocol in collaboration with the EH, the participant is able to identify the impact of these decisions, challenges or values on public (external) values, as depicted in figure 1. It is the EH's task to guide the participant through these iterations by using techniques like *probing* and *nudging*.

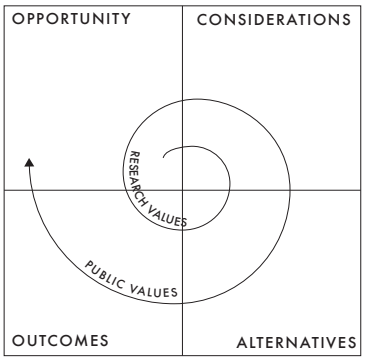

Figure 1: Decision Protocol (research values impact public values)

3.3.2 Coding segments for traditions and modulations

The audio of each session was recorded on a laptop and thereafter imported into QSR NVivo, a software solution for qualitative data analysis. QSR NVivo was used to describe and code communication segments taken from the sessions as well as to provide them with a time stamp.

Working towards building the communication model required MM communication to be characterized with respect to the communication traditions. The segments, which are bits of communication, were coded for the seven communication traditions as follows: CRI (critical), CYB (cybernetic), PHE (phenomenological), RHE (rhetoric), SEM (semiotic), SCU (sociocultural) and SPS (sociopsychological). During coding, the question was how and when a communication segment qualified as a representation of a particular tradition or a combination of traditions. Table 1 is a useful tool in categorizing communication segments per tradition. The table rows provide brief examples of communication, problems of communication, meta-discursive vocabulary, meta-discursive commonplaces and their challenges for each tradition. Especially the theorization and the meta-discursive vocabulary appeared to be very useful in practice.

The following example describes an emotionless exchange of factual information and fits best, based on the vocabulary from Table 1, within the cybernetic tradition; source, receiver, signal, information etc. On the other hand, the segment describes communication that involves drawings to help explain mechanical principles, which is a form of mediation by symbols and connects best to the semiotic tradition.

CYB + SEM: P1 explaining more of the mechanical principles of the new IP, mediated by drawings.

A second example of how segments are coded is shown below. The EH probes the participant to consider solutions for the issue at hand. Doing so, fits the rhetoric tradition since probing is methodical and strategic communication with the goal of investigating one's thoughts or feelings.

RHE: EH trying to see (probe) if P2 can use his experience from Comp A in solving the current issue. What was different/similar when the liquidity was low? P2 says the situation was different because of the shared values of P1 and P2 concerning the need of a salary and the amount. They had no trouble looking for side jobs (PostNL) of skipping a pay check in order to make investments. P2 understands that each person has its own experience to what is acceptable where that is concerned. He decided to propose the same hourly fee to all the members. This has raised objections.

One might ask why this segment is not coded as PHE as well (see Table 1 for explanation). Although the EH takes a phenomenological angle by asking P2 about his past experiences in dealing with low liquidity, the phenomenological tradition does not characterize the nature of the communication itself. Being able to separate the *content* and *nature* of communication has been very important during this study.

When a modulation was observed in a particular segment, it was coded as either MOD_DFCT (de facto), MOD_RFLX (reflexive) or MOD_DLBRT (deliberate). In practice, it was possible for a particular segment to be described by multiple traditions in combination with a modulation. The example below shows how the participant's earlier reflection has led to decisions that actually changed his professional actions, hence the code MOD_DLBRT.

CYB + MOD_DLBRT: P3 informing EH about his new way of sharing knowledge from now on. His awareness led him to the concept of info-packaging; you don't want to send a package to light (waste) or to heavy (slow, rigid) but

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just right so people know what they are supposed to do with the content;
either answer a question, think along or take action (own words).
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The recordings of the MM communication were divided into segments with a duration varying from several seconds to a few minutes. The actual length of the segments was not set beforehand. Most often, the start of a segment was marked by either a question of the EH or a clear change of subject. The end of a segment was most often marked by the participants answer. Opposed to a protocol, these are more practical and natural ways to 'cut off' segments.

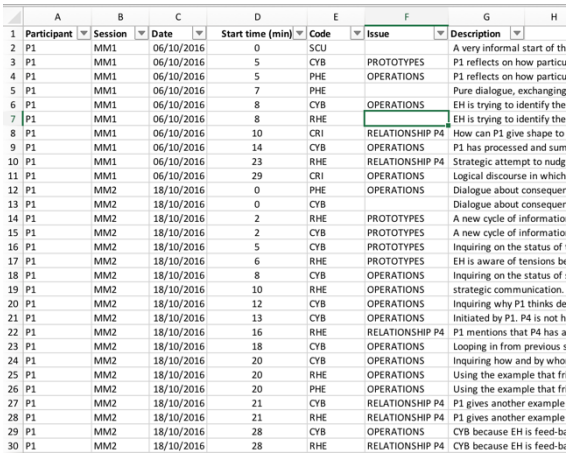
The goal of section 3.2.2 is merely to demonstrate the method applied in coding segments of MM communication. The examples used are actual data from the case study. Although the Methods section traditionally is not used to present actual data, I deemed it useful to present a few examples in order to give practical insight in the method applied for coding communication segments.

3.3.3 Introducing 'Issues'

When designing this study, it was important for it not become a singular exercise of Communication Science. The conviction that integration studies like STIR should not only be practiced and shaped by social scientists was the driver behind the introduction of a new concept, being the aforementioned parameter called *issue*. Issues are defined as *recurring themes, that strongly influence professional agendas of participants in midstream modulation trajectories.* The nature of the 'issues' depends on the context of the study and is revealed during the course of the MM trajectory. Introducing 'issues' allows us to cluster communication interactions in tangible, straightforward categories familiar to technical experts and other professionals who do not have any knowledge of communication science or ethnographic sociology. Making results of studies such as these tangible and easy to understand for all professionals, is in accordance with the need for more inclusive design methods mentioned in the introductory chapter.

3.3.4 Excel database structure

The next step in data processing was building a database structure in Excel. The time stamps, codes for traditions and modulations as well as the descriptions of the segments were exported from QSR NVivo as .txt files and imported into Excel. In Excel, the codes for issues were added to the list of parameters along with columns for 'participant' (e.g. P3), 'session' (e.g. session number 4 was coded as MM4) and 'date'. Inserting filters at the top of each column and creating pivot tables, allowed for on-the-fly investigations of parameter developments in relation to any other parameter, as shown in figures 2 and 3. The digital appendix provides a fully operable database structure to experiment with.



	A	B	C	D	E	F	G
1	Participant	Session	Date	Start time (min)	Code	Issue	Description
2	P1	MM1	06/10/2016	0	SCU		A very informal start of th
3	P1	MM1	06/10/2016	5	CYB	PROTOTYPES	P1 reflects on how particu
4	P1	MM1	06/10/2016	5	PHE	OPERATIONS	P1 reflects on how particu
5	P1	MM1	06/10/2016	7	PHE		Pure dialogue, exchanging
6	P1	MM1	06/10/2016	8	CYB	OPERATIONS	EH is trying to identify the
7	P1	MM1	06/10/2016	8	RHE		EH is trying to identify the
8	P1	MM1	06/10/2016	10	CRI	RELATIONSHIP P4	How can P1 give shape to
9	P1	MM1	06/10/2016	14	CYB	OPERATIONS	P1 has processed and sum
10	P1	MM1	06/10/2016	23	RHE	RELATIONSHIP P4	Strategic attempt to nudg
11	P1	MM1	06/10/2016	29	CRI	OPERATIONS	Logical discourse in which
12	P1	MM2	18/10/2016	0	PHE	OPERATIONS	Dialogue about consequer
13	P1	MM2	18/10/2016	0	CYB		Dialogue about consequer
14	P1	MM2	18/10/2016	2	RHE	PROTOTYPES	A new cycle of informatio
15	P1	MM2	18/10/2016	2	CYB	PROTOTYPES	A new cycle of informatio
16	P1	MM2	18/10/2016	5	CYB	PROTOTYPES	Inquiring on the status of
17	P1	MM2	18/10/2016	6	RHE	PROTOTYPES	EH is aware of tensions be
18	P1	MM2	18/10/2016	8	CYB	OPERATIONS	Inquiring on the status of
19	P1	MM2	18/10/2016	10	RHE	OPERATIONS	strategic communication.
20	P1	MM2	18/10/2016	12	CYB	OPERATIONS	Inquiring why P1 thinks de
21	P1	MM2	18/10/2016	13	CYB	OPERATIONS	Initiated by P1. P4 is not h
22	P1	MM2	18/10/2016	16	RHE	RELATIONSHIP P4	P1 mentions that P4 has a
23	P1	MM2	18/10/2016	18	CYB	OPERATIONS	Looping in from previous s
24	P1	MM2	18/10/2016	20	CYB	OPERATIONS	Inquiring how and by who
25	P1	MM2	18/10/2016	20	RHE	OPERATIONS	Using the example that fr
26	P1	MM2	18/10/2016	20	PHE	OPERATIONS	Using the example that fr
27	P1	MM2	18/10/2016	21	CYB	RELATIONSHIP P4	P1 gives another example
28	P1	MM2	18/10/2016	21	RHE	RELATIONSHIP P4	P1 gives another example
29	P1	MM2	18/10/2016	28	CYB	OPERATIONS	CYB because EH is feed-ba
30	P1	MM2	18/10/2016	28	RHE	RELATIONSHIP P4	CYB because EH is feed-ba

Figure 2: Excel sheet with filters on each parameter column

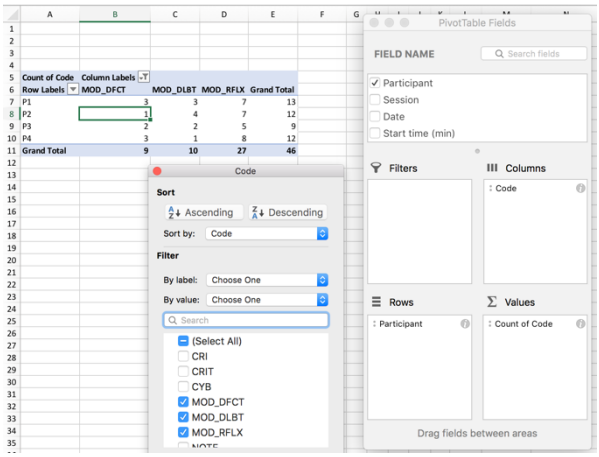


Figure 3: An example of a pivot table

Each segment of communication between the EH and the technical expert that exemplifies a particular communication tradition or a modulation was coded for that specific tradition or modulation. Initially, the segments were designated to a single row in Excel. Besides the more administrative parameters *participant, session, date* and *start time* (marking the start of an interaction) the parameters *code* (traditions and modulation), *issue* and *description* provided information about the particular modulation and/or traditions, the particular issue and a description of the segment at hand. If a segment was characterized by more than one tradition, or a combination of traditions and a modulation, it was copied onto a next row until each row had a single value in the code column. Often times these multi-traditional interactions fit more than one issue as well. Processing the interaction in this manner enabled me to categorize a single segment into multiple issues. Creating (graphical) representations of (a selection of) traditions against time or a particular issue against (a selection of) modulations, for either a specific participant or a larger selection, was now fairly easy to do.

The method of data processing presented above has never been applied in any other related research of communication. During this study, a total of 691 segments were coded for communication traditions and modulations. The fact that there was approximately 17 hours of audio recorded, gives an idea of the segment-density. A higher density of segments allows researchers to construct a more accurate representation of the original, 'unsampled' communication, opposed to maintaining a lower density and consequently, missing important data in between segments. Having detailed descriptions of the segments and the flexibility of the Excel database structure, enables us investigate if and how communication characteristics change over time, per participant or even per issue. Previous studies have not been focused on identifying the characteristics of MM communication in such manner.

4. Results

The following chapter presents the results based on the Excel database structure discussed in chapter 3. Having the database structure in place, permits us to plot issues, modulations, participants and time against each other, in order to detect the characteristics and dynamics of the communication that took place during the MM sessions. Sections 4.1 to 4.3 present new insights and examples concerning the specific issues, their related modulations and the communication traditions that show to be relevant to this case study. In sections 4.4 and 4.5 the traditions are clustered per session 'date', providing an overview of the entire MM trajectory, as well as 'start time', showing when and how traditions appear within an MM session. Finally, in section 4.6, the Midstream Modulation Communication Model (MMCM) is hypothesized based on the results presented in preceding sections and the segment descriptions from the Excel database structure.

4.1 Issues

In section 3.3.3, issues are defined as "*recurring themes, that strongly influence professional agendas of participants in midstream modulation trajectories".* During data processing, nine issues were identified within the case study. The following section briefly describes all of the issues. The digital appendix provides an in-depth view of all individual segments specific to a particular issue. The descriptions of a particular issue can be viewed by selecting the issue of interest on the filter of the issue-column.

BALLOON TROCAR is a design-related issue. The team is designing a product family of medical devices for surgeons who perform laparoscopic interventions. One of these products is a balloon trocar. A trocar primarily consists of a hollow tube (cannula) that is inserted through a tiny incision (key hole) in the abdomen. During surgery, the trocar serves as a portal through which a variety of instruments can enter and manipulate various tissues. The balloon encloses the trocar and is inflated on both sides of the abdomen ensuring fixation during the procedure.

FINANCE is the issue that primarily entails grant applications, financial planning of the R&D trajectory and salaries. The context of this issue is determined by Company A, B and C attempting to form a cooperative and corporate structure despite some fundamental differences in team perception and R&D priorities.

KNOWLEDGE SHARING is the issue that plays an important role in the collaboration between, predominantly, P1 and P3. The question "when do you share an idea?", is the central question that leads to a reevaluation of the collaboration amongst some of the team members.

OPERATONS is the issue that involves attempts of the team to set up a corporate structure as well as a collaboration structure between Company A, B and C. This issue reveals how some participants have opposing views on team roles, on the focus of R&D and on how tasks should be executed in general.

PROFESSIONAL DEVELOPMENT is the issue that covers MM-encounters where the participant shows some sort of reflection on their professional development. The reflection is not necessarily limited to professional development within the project. The contentious nature of the collaboration seems to make experts think about their professional future outside of the project as well.

PROTOTYPES is the issue that revolves around misunderstandings and disagreements concerning the construction, requirements and purpose of laparoscopic grasper prototypes. MM was able to provide insight in this indistinctive and, to some participants, quite frustrating process.

RELATIONSHIP P4 is the issue that entails the problematic relationship of P4 with the other team members. The root of the aggravation, especially between P4 and P1, stems from fundamentally different views on the corporate structure. P4 sees himself, unjustly, as the primary innovator of the compliant grasper who has formed a team around himself to support his vision. The other participants share a more horizontal view on the collaboration and see that Company B and C bring expertise, patents and funding to the table which makes them equal partners. The severity of the relationship's poor shape is reflected on many of the other issues.

TEST SETUP has a quite similar nature to the issue PROTOTYPES. There is no consensus about the construction, requirements, purpose or even the location of the test setup for the laparoscopic device.

TOOLTIP FUNCTION is a design-related issue about the compliant character of the tooltip and its locking mechanism. The recurring question is whether these features make the grasper more susceptible for unpredictable tooltip behavior and failure during surgery, both of which could have serious medical consequences for the patient.

The nature of the issues differs from very technical to rather personal. Neither of the issues have strict boundaries but rather show overlap and fluidity in most occasions. For instance, a design-related issue may have impact on the project's finance and a disagreement about financial matters may influence a relationship.

4.2 Modulations

The following section presents the modulations that were identified throughout the course of the MM trajectory. First, in section 4.2.1, the modulations are briefly discussed per issue in the form of table 3a to 3g. In the issues BALLOON TROCAR and TOOLTIP FUNCTION, no modulations are observed. In order to explore how modulations come to existence and how they follow each other up over time, the modulations of two issues, FINANCE and KNOWLEDGE SHARING, are elaborately described in sections 4.2.2 and 4.2.3. A full overview of the modulations and their descriptions can be found in the digital appendix. Viewing the appendix is highly recommended to understand the full scope of the MM trajectory.

4.2.1 Overview

The modulations that involve the issue FINANCE are discussed in section 4.2.2.

FINANCE	***23/11/2016***	***08/03/2017***	***04/04/2017***	***Grand Total***
P2	**1**	**1**	**1**	**3**
MOD_DLBT	1		1	2
MOD_RFLX		1		1
Grand Total	**1**	**1**	**1**	**3**

Table 3a: FINANCE, all participants per issue

The modulations that involve the issue KNOWLEDGE SHARING are discussed in section 4.2.3.

KNOWLEDGE SHARING	***08/03/2017***	***14/03/2017***	***15/03/2017***	***Grand Total***
P1		**1**		**1**
MOD_DFCT		1		1
P3	**2**		**5**	**7**
MOD_DFCT	1		1	2
MOD_DLBT			2	2
MOD_RFLX	1		2	3
Grand Total	**2**	**1**	**5**	**8**

Table 3b: KNOWLEDGE SHARING, all modulations per participant

OPERATIONS is the issue in which most modulations were observed. Also, it is the only issue with modulations by all four participants. The modulations are well spread out over the course of the MM trajectory. Similar to KNOWLEDGE SHARING, the issue OPERATIONS shows how MM is also used as a means to organize collaboration between multiple technical experts. Note: The columns of figure 3c are clustered per month and not per date for the table to fit the page.

OPERATIONS	Oct '16	Nov '16	Dec '16	Mar '17	Apr '17	Grand Total
P1	**2**		**1**			**3**
MOD_DLBT	1					1
MOD_RFLX	1		1			2
P2	**3**	**1**	**1**	**3**	**1**	**9**
MOD_DFCT	1					1
MOD_DLBT			1		1	2
MOD_RFLX	2	1		3		6
P3				**1**		**1**
MOD_RFLX				1		1
P4	**2**	**1**	**1**			**4**
MOD_DFCT	1		1			2
MOD_RFLX	1	1				2
Grand Total	**7**	**2**	**3**	**4**	**1**	**17**

Table 3c: OPERATIONS, all modulations per participant

The issue PROFESSIONAL DEVELOPMENT is self-explanatory: a rather personal issue about the participant's view on his own professional development. Nevertheless, three short examples are given to illustrate the modulations of the issue. P1's MOD_RFLX of 21/10/2016 is followed by a discursive reflection about the value of MM. P1 jokes that the EH is a tool to gain insight in finding out why it is so difficult to build a team.
P1's second MOD_RFLX is of a more personal nature. He asks himself if being an entrepreneur is satisfactory, seeing how this project is developing.
P3's MOD_RFLX follows from him seeing the importance of knowledge sharing in other projects and situations as well, showing a change in his general professional development.

PROFESSIONAL DEVELOPMENT	26/10/2016	17/01/2017	15/03/2017	Grand Total
P1	**1**	**1**		**2**
MOD_RFLX	1	1		2
P3			**1**	**1**
MOD_RFLX			1	1
Grand Total	**1**	**1**	**1**	**3**

Table 3d: PROFESSIONAL DEVELOPMENT, all modulations per participant

The issue PROTOTYPES is rather technical. P4 is planning to use aluminum fillers in combination with a laser-welded joint to attach the compliant grasper onto the shaft. The EH openly questions whether using aluminum fillers and laser-welding are appropriate measures for a medical tooltip. P4 understands the EH's point. He says that maybe he should re-iterate with the external welding partner since he assumed the connection would be medically certified. P4 does not seem to have done his own research yet and trusted the external welding partner despite reservations voiced by P1. MOD_DFCT observed as P4 only now appears to understand the potential challenges of this design element in terms of CE certification.
Later on, in the same session, P4 reflects on what he could have done differently to avoid doubt and possible misunderstanding. He would have told the welding partner, up front, to provide more information instead of assuming the partner was right.

PROTOTYPES	18/10/2016	Grand Total
P4	**2**	**2**
MOD_DFCT	1	1
MOD_RFLX	1	1
Grand Total	**2**	**2**

Table 3e: PROTOTYPES, all modulations per participant

RELATIONSHIP P4 is an issue that is widely discussed in sessions with each participant. However, only in sessions with P1 and P4 modulations were observed. Most modulations involve realizations of (and reflections on) how the troublesome relationship impacts the team's ability to make decisions in other issues. MOD_DLBT's involve changes in the way that participants communicate with one another as well as the deliberate decisions, which follow from MM interventions, to give up on trying to mend the relationship. Note: The columns of table 3f are clustered per month and not per date for the table to fit the page.

RELATIONSHIP P4	Oct '16	Nov '16	Dec '16	Jan '17	Feb '17	Grand Total
P1	**3**		**1**	**1**	**1**	**6**
MOD_DFCT	2					2
MOD_DLBT			1	1		2
MOD_RFLX	1				1	2
P4		**4**	**1**	**1**		**6**
MOD_DLBT				1		1
MOD_RFLX		4	1			5
Grand Total	**3**	**4**	**2**	**2**	**1**	**12**

Table 3f: RELATIONSHIP P4, all modulations per participant

TOOLTIP FUNCTION is a design-related issue that especially has P1's attention. On January 17th 2017, the EH asks P1 to reflect on how his recent ideas for the tooltip connection (TTC) came about. The EH asks if P1 knows if there was a specific moment when he felt triggered to think about the TTC. P1 says the trigger was annoyance and the knowledge that the buckling needed to be gone. "In hindsight, the TTC and the buckling are unreliable and should not have been explored so extensively", he adds.

TOOLTIP FUNCTION	17/01/2017	Grand Total
P1	**1**	**1**
MOD_RFLX	1	1
Grand Total	**1**	**1**

Table 3g: TOOLTIP FUNCTION, all modulations per participant

Modulations are observed with each participant and on all three levels (de facto, reflexive and deliberate). Although every issue is discussed with each participant, OPERATIONS is the only issue with modulations by all participants. In the issues BALLOON TRACAR and TEST SETUP, although thoroughly discussed, no modulations were observed. The nature of the modulations is as diverse as the issues are. There are changes established in how participants communicate, organize and innovate within the project. Modulations within PROFESSIONAL DEVELOPMENT impact activities outside of the project as well.

4.2.2 Example 1: FINANCE

P2, MOD_DLBT, November 23rd 2016

During P2MM1, P2 reports that it is really difficult to make a budget and a project planning through open discussions with all team members. There are, simply put, too many opposing opinions. An outcome of P2MM1 is the decision of P2 to take charge of the situation by proposing the budget and the project plan to Comp B and C individually, instead of having horizontal discussions with all parties. He processes their input and, only then, sends the result to the entire team. This change in work flow is a MOD_DLBT established through MM. When the EH inquires if the MOD_DLBT is causing more or less trouble than before, P2 acknowledges the difference because now team members have to provide him with arguments to why the budget is not good, opposed to P2 being the one trying to make a budget from scratch with a divided team. “The latter has no results, the first does”, P2 adds.

P2, MOD_RFLX, March 8th 2017

During P2MM4, the EH shares his concerns about some technical liabilities of the grasper and asks P2 how the project was able to receive the STW grant with these liabilities. This leads to P2 reflecting on what the team should have done better: fundamental tests concerning dynamic behavior and loads. "We needed the legendary test bench", P2 adds, referring to the lack of direction in building a test setup.

P2, MOD_DLBT, April 4th 2017

After the exit of Company C and P4, the team had to reapply for the STW2 grant. Leading up the presentation of the revised project plans and the new IP, P2 and the EH dedicated an MM session to prepare for the possible pitfall of addressing P4’s exit in a way that reflects badly on the project as well as for building a logical and consistent story for the STW committee. During the session, the EH makes notes of ideas and possible scenarios for the presentation. At the end of the session P2 asks if he can take a picture of EH’s notes, indicating the deliberate decision to incorporate considerations and outcomes of the session into the final presentation.

Example 1 shows that P2 was the only participant that showed FINANCE modulations. This does not mean that the issue was not spoken about with other participants. It is likely that modulations were only observed with P2 because he is the only participant whose main tasks entail planning and budgeting. The last MOD_DLBT shows how MM can develop into collaboration between EH and participant.

4.2.3 Example 2: KNOWLEDGE SHARING

P3, MOD_DFCT, March 8th 2017

In an earlier session, P1 has shared his concern about P3 not sharing ideas and knowledge. The EH wants to find out why P3 could be reluctant to share and carefully opens up the conversation by sharing his assumptions about the concept of static balancing (SB). Based on findings from P1MM7, the EH nudges P3 to give his version of the story. At that moment P3 realizes that the moment of knowledge sharing is an interesting point to consider in ideation processes.

P3, MOD_RFLX, March 8th 2017
The EH introduces the term “under-sharing” as not sharing ideas or sharing ideas too late. He asks if P3 under-shares because he is afraid to come across as stupid. P3 understands the meaning of the questions and agrees to an extent. He adds that it is not fear-driven or that P1 makes him feel stupid but that it is rather fed by the aim to impress P1. P3 recognizes P1 as a very accomplished engineer he looks up to and wants to impress. P3 shows reflexivity based on the MOD_DFCT earlier this session. The realization of knowledge sharing being an issue in the team has evolved to a heightened awareness of P3's part in under-sharing in relation to P1. The underlying psychosocial reasons came to the surface thanks to MM. P3 remarks that the EH has made a very good observation.

P1, MOD_DFCT, March 14th 2017
During the session P1 and the EH do not seem to reach a deeper understanding of the issue KNOWLEDGE SHARING. In another attempt to have P1 reflect on his opportunities to tackle this issue, the EH summarizes how the issue came about. P1 responds that he has not seen any changes in the way P3 reacts to what is shared since P3MM7. The EH interjects by saying it's not about reacting to [...]. P1 interjects by saying "no but about being proactive about sharing new ideas”. Only now the issue seems to be fully recognized by P1. NOTE: on March 21st 2017 P1 reached out to the EH via WhatsApp apologizing for not being on his best behavior during P1MM8. He commended the EH for his efforts and showed a screen shot of a WhatsApp conversation showing that he has taken the effort to speak about the issue with P3. This was exactly the goal of EH’s nudges during P1MM8 so P1’s decision to reach out to P3 might be seen as an off-record MOD_DLBT.

P3, MOD_RFLX, March 15th 2017
P3 says he has thought about knowledge sharing and concludes that there should be no reason to withhold knowledge sharing since all IP will be controlled by one company.

P3, MOD_RFLX, March 15th 2017
P3 elaborates that this situation is a good exercise in establishing a culture where knowledge sharing is the norm.

P3, MOD_DLBT, March 15th 2017
P3 has, since the last session, shared all details concerning SB with P1 but, more importantly, he has reached out to P1 for his expertise on filing IP claims. P3 is less experienced in that respect so he set up the collaboration between him, P1 and the patent lawyer in Iceland, proactively asking P1 for help and support.

P3, MOD_DLBT, March 15th 2017
P3 informs the EH about his new way of knowledge sharing. His awareness has led him to the concept of “info-packaging”: you don't want to send a package to light (waste) or to heavy (slow, rigid) but just right so people know what they are supposed to do with the content; either answer a question, think along or take action. This segment shows how P3 has clearly been able to transform an issue that he initially was not aware of, to one of his main priorities within the project.

P3, MOD_DFCT, March 15th 2017
EH asks if P3 sees room to apply his new-found awareness in different or future projects. As P3 continues he explains that a pitfall for collaboration is to assume that the collaborator knows what you know. "Who am I talking to? What do they know and need to know in order for them to be able to collaborate? If you can't establish that, you are not collaborating but you are presenting", P3 says. He adds that if you want to get something out of the collaboration you have to make sure you've given the information needed to collaborate.

Example 2 shows how the EH, based off P1's concerns, triggers P2 to become mindful about knowledge sharing. MM facilitated the process of growing this heightened awareness into reflexivity and even deliberate changes in collaboration and professional development, which also shows the aforementioned overlap of issues. Finally, example 2 shows how EH organizes the change in collaboration between P1 and P3.

4.3 Context and application of communication traditions

The following section is a brief overview of the context and application of each communication tradition in light of the case study. Understanding the context and application of communication traditions, as well as knowing how often they are observed, is important is understanding the characteristics of MM communication. The overview is a summary of the Excel database, filtered for each tradition and their corresponding descriptions. The patterns that are seen in these descriptions, in terms of context and application, are explained below. For an elaborate overview of the traditions and their full descriptions it is advised to study the digital appendix.

Critical (CRI)
There is a total of 39 interactions coded with this tradition. The critical tradition mainly is seen in discursive reflections where considerations for future decisions are being examined. The tradition also appears in interactions where EH becomes quite forward in his efforts to establish modulations. It is within the critical tradition that the EH resorts to explicitly sharing a vision on an issue. Based on information that the EH acquires throughout the sessions with different participants, he is able to identify misconceptions which are then, if deemed necessary, forwarded in the form of critique.

Cybernetic (CYB)
There is a total of 207 interactions coded with cybernetic tradition. The tradition is mainly seen in instances where EH acquires, links and redistribute information from and between participants and where data are compared over time and between participants. The multi-actor design of the case study, requires the EH to create a database of all the opportunities, considerations, alternatives and outcomes of each individual session. This database is also linked to EH's personal (academic) background and (professional) experiences, which helps creating perspectives that are useful to the R&D trajectory.

Phenomenological (PHE)
There is a total of 46 interactions coded with the phenomenological tradition. The tradition is observed where the EH or the participant exchanges personal experiences that are, often but not exclusively, related to the issue that is being discussed. The deployment of the

tradition is based on genuine exchanges without explicit rhetorical motives from neither the EH or the participant. Because of its personal signature, the phenomenological tradition appears to indicate the status of the informal relationship between EH and the participant.

Rhetorical (RHE)
There is a total of 254 interactions coded with the rhetorical tradition. The tradition is seen where EH nudges the participant towards (re)considering opportunities or alternatives as well as to reflect on their activities. Also, rhetoric is often used by the EH in probing the participant for opinions, ideas and even sentiments regarding any of the nine issues. Generally, the rhetorical tradition appears to matter most when the EH strategically chooses to either use or leave out words and information in order to establish particular goals during MM sessions.

Sociocultural (SCU)
There is a total of 2 interactions coded with the sociocultural tradition. The tradition has only been observed in two instances where the EH explained the MM procedures to P1 and P2, establishing a social order for the upcoming sessions.

Semiotic (SEM)
There is a total of 27 interactions coded with the semiotic tradition. The tradition is observed in three different types of interactions. Firstly, the semiotic tradition characterizes communication that is mediated by drawings or sketches as a means to explain and discuss (technological) issues. Secondly, the semiotic tradition is observed in instances where figurative symbols or images are used to explain characteristics of actual matters. Expressions like “it’s as if” or “kind of like”, characterize these observations. The third and final situation where the semiotic tradition is observed, is when misunderstandings occur about the actual meaning of a concept or a word. For instance, MM sessions revealed that P1 and P4 have different definitions of (and associations with) the same word “prototype”, which leads to false expectations and agitation.

Socio-psychological (SPS)

There is a total of 65 interactions coded with the socio-psychological tradition. The tradition is predominantly observed in emotive expressions from the participants towards the EH. In this particular study, most of these expressions are based on a range of feelings such as anger, frustration, fear and indifference. The communication is not always verbal. Sighs, huffs or the change in tone may indicate emotive expressions as well. The socio-psychological tradition is not prohibited to participants alone. In a small number of instances, the EH shows emotive expressions as well.

ISSUES VS. TRADITIONS	CRI	CYB	PHE	RHE	SCU	SEM	SPS	Grand Total
BALLOON TROCAR	1	6	1	4		3		15
FINANCE	4	21	1	20		2	10	58
KNOWLEDGE SHARING	8	10	4	28			5	55
OPERATIONS	12	73	12	84		4	22	207
PROFESSIONAL DEVELOPMENT	1	5	2	9			3	20
PROTOTYPES	5	21	1	20		3		50
RELATIONSHIP P4	6	31	5	56		3	19	120
TEST SETUP		18		10		3	1	32
TOOLTIP FUNCTION	1	13	2	16		7	3	42
NO ISSUE (blank)	1	9	18	7	2	2	2	41
Grand Total	**39**	**207**	**46**	**254**	**2**	**27**	**65**	**640**

Table 4: ISSUES VS. TRADITIONS, all participants

Table 4 is an overview of the observed traditions categorized per issue. The most observed traditions are by far CYB and RHE, showing that acquiring, linking and redistributing information, as well as probing and nudging are done very frequently throughout the MM process. CRI is seen at discursive reflections and more disputative interactions between the participants and the EH. PHE is observed in exchanges of personal experiences which are often, but not exclusively, related to the issue that is being discussed. PHE appears to indicate the status of the informal relationship between the EH and the participant. SEM is mostly observed in communication that is mediated by literal or figurative symbols like drawings or sketches or analogies, respectively. SPS is predominantly observed in emotive expressions and SCU is observed only twice in issue-unspecific communication where the process and boundaries of MM are explained.

4.4 Communication traditions versus 'date'

The following section introduces the parameter 'time'. Figure 4 consists of plots of the traditions observed during a session against the date of that particular session. The traditions are clustered per participants to identify if and how their appearance changes per person. Possible similarities or differences in the appearance of traditions are important notice in order to answer identify the characteristics of MM communication.

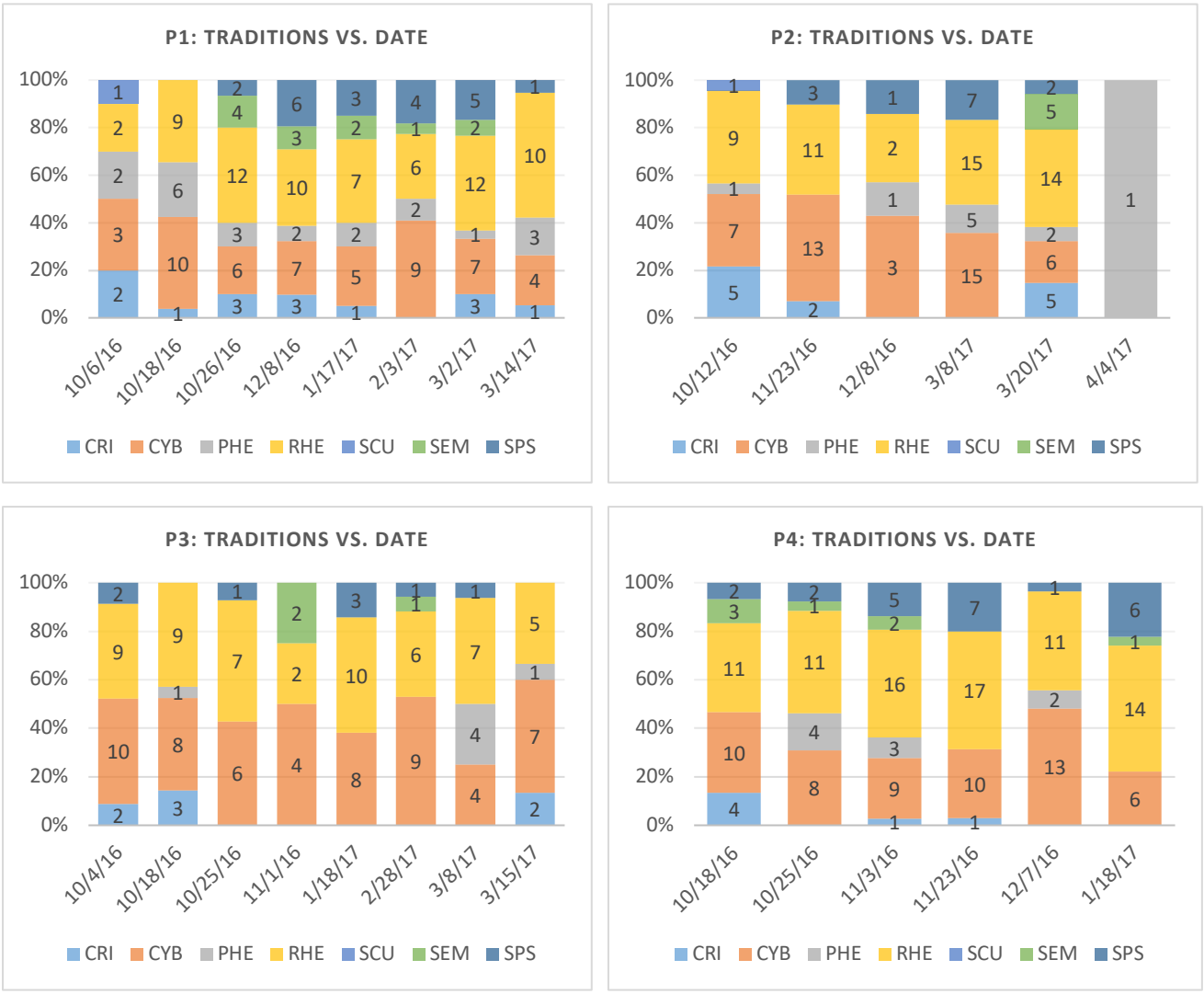


Figure 4: TRADITIONS VS. DATE per participant

Figure 4 shows large bandwidths of RHE and CYB for all participants throughout the entire MM trajectory. The high occurrence of these traditions was already observed in section 4.3. However, now we see that CYB and RHE do not seem to depend on the participant, nor on a particular point in time.

PHE is consistently observed during the sessions with P1, which seems to confirm that PHE indicates the quality of an informal relationship. At the origin of this study, P1 was the first person who had been approached for his cooperation. The fact that P1 and the EH got acquainted prior to starting the MM sessions might have contributed to the more personal, informal and genuine interactions. In accordance with the latter, the phenomenological tradition appears more often deeper into the trajectories of P2 and P3, indicating a more personal and less formal relationship has developed. At the same time, the absence of PHE

in the interactions with P3 could be explained by the fact that the sessions took place via Skype calls, opposed to face-to-face. During P4's trajectory, PHE disappears over time. This might seem contradicting but it is in fact showing again that PHE is an indicator of the informal relationship status. As the tension grew within the team and P4's part in creating the tension became more obvious to the EH, the relationship took on a more formal character.
Generally, the sessions with P1 show a high count and variety of traditions compared to the other participants. The sessions with P3 show less variety, as well as a relatively low density of traditions. Only a few times SEM was observed in P3's sessions. Although the sessions with P3 covered technical issues, the communication was hardly ever mediated by drawings or sketches, even after repeated requests by the EH to provide these as a means to facilitate the MM sessions. The little observations of SEM in the sessions with P2 are explained by the fact that FINANCE, a non-technical issue, was observed the most.
Finally, the fact that SPS is observed throughout each individual trajectory indicates the importance of emotive expressions in this particular R&D trajectory.

4.5 Communication traditions versus 'start time'

The communication traditions and modulations are now plotted against the parameter 'start time' in order to identify possible dynamics in communication during individual MM sessions. Figure 5 summarizes how the communication traditions are alternated during typical MM sessions. Because the high number of sessions in the case study (28), only a selection of one session per participant is used to investigate the dynamics of the communication traditions within MM sessions. All sessions in the selection contain at least one modulation in order to investigate possible typical patterns or characteristics around the time of a modulation.

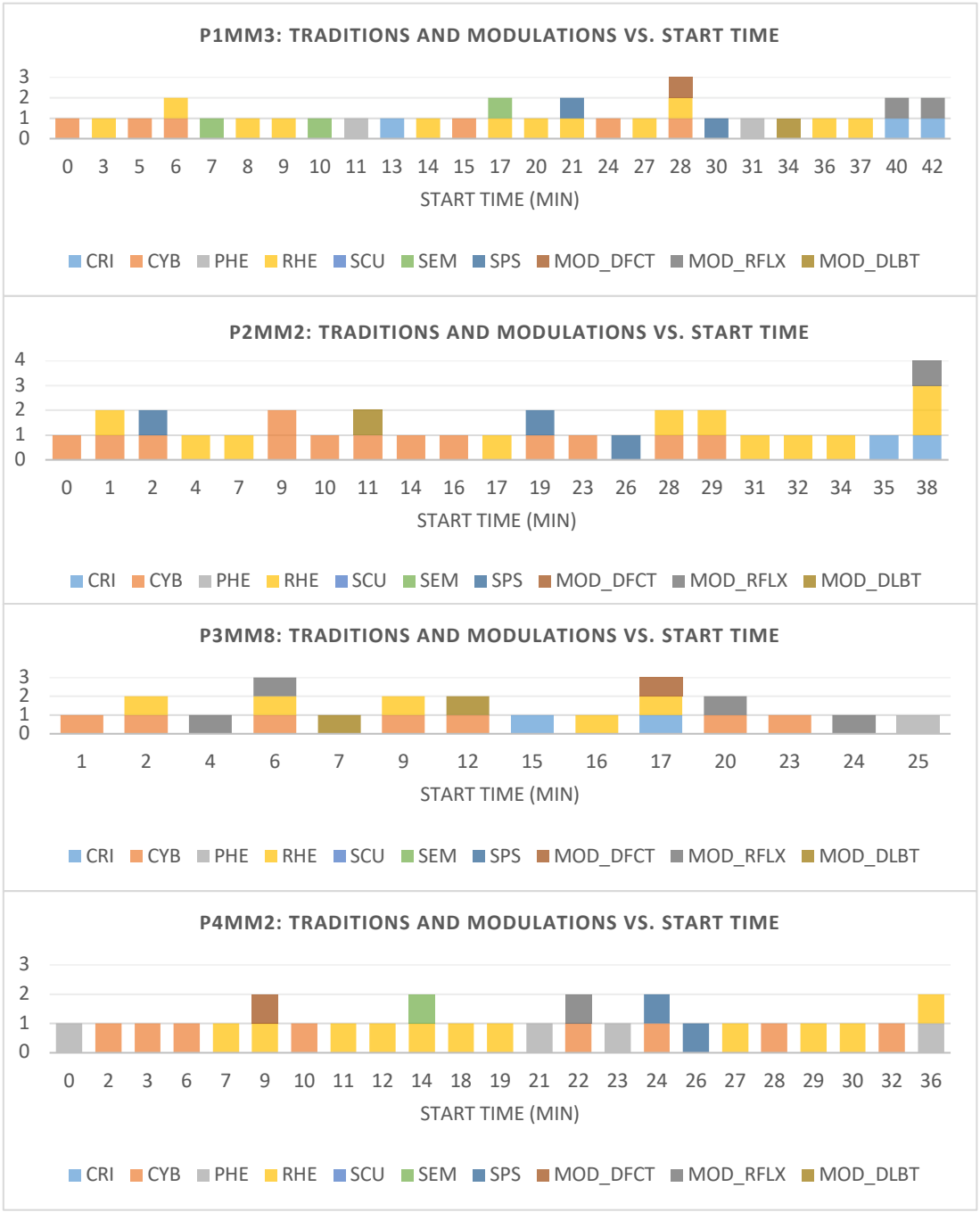


Figure 5: TRADITIONS AND MODULATIONS VS. START TIME per participant

Figure 5 shows that single interactions could contain multiple communication traditions. This indicates the multifaceted nature of communication interactions. All sessions have multiple things in common. Firstly, we see that CYB and RHE are, almost constantly, observed very close to one another, which indicates that the EH's cybernetic activities are closely connected to his rhetorical activities. The outcomes of acquiring, redistributing and comparing information determine if and how participants are nudged and probed by the EH. The outcomes of cybernetic activities influence the rhetorical activities that follow, and vice versa, much like a feedback loop. Secondly, in all sessions, modulations are preceded by either RHE or CRI, which reinforces earlier findings from literature about the influence of the EH's deliberate activities on the decision-making process of technical experts.

4.6 The Midstream Modulation Communication Model

Sections 4.1, 4.2 and 4.3 provided insights and examples concerning the specific issues, modulations and communication traditions. In sections 4.4 and 4.5 the parameter 'time' was introduced on two levels. The occurrence of traditions was clustered per session 'date', providing an overview of the entire MM trajectory, as well as per 'start time', showing when and how traditions appear within an MM session. The goal of section 4.6 is to hypothesize the Midstream Modulation Communication Model (MMCM) based on the results presented in the preceding sections and the segment descriptions from the Excel database structure.

The examples of sections 4.2.2 and 4.2.3 show how modulations, per issue, typically follow each other up. What stood out, while compiling the examples, is how the communication appears to have three stages: The first stage is the identification of an issue. The second stage is the development of the modulation. The third and final stage is the assessment of the modulation, which technically is not a stage of communication since this stage only involves the EH.

In order to demonstrate how the stages follow up each other on a description level, a filtered table is created for the example presented in 4.2.3. Table 5 is a crop of the Excel database, filtered as follows: **Participant** (P1), **Session** (MM7) and **Issue** (KNOWLEDGE SHARING). The passages highlighted in yellow in the 20th minute, mark the *identification of the issue*, which I consider the first stage of MM communication. The second stage of MM communication commences, which is the *development of a modulation*, can be viewed in the passages highlighted in green at the 22nd and 24th minute. The third stage, the assessment of the modulation, is the task of the EH and takes place regularly during the session. The outcome of the third stage, for this particular session at least, is that there is no modulation established. Therefore, stages 1 and 2 are repeated at the 25th and 30th minute, respectively highlighted in yellow and green again.

Participant	Session	Date	Start time	Code	Issue	Description
P1	MM7	02/03/2017	20	CRI	KNOWLEDGE SHARING	Discursive discussion about knowledge sharing in these types of projects. This is triggered by P1 pointing out at the end of the previous section that he was not aware of certain test setup P3 had built for the grasper while EH was able to show him SW drawings. "P3 should share those things with me", he says. EH asks why P1 thinks somethings are not communicated/shared within the team. P1 points out cultural differences. P1 explains there has been a lack of sharing as well as a lack of interest up until sharing becomes vital at the last minute [of a dead line]. EH responds by saying that that is the danger. Organization of R&D is so much easier with less last-minute calls when members are aware of what their colleagues are working on. P1 says, "Yeah, but you have got to want it", "understand the purpose of it...", EH adds. P1 agrees and continues by pointing there's a difference in sharing due to a difference in experience. "Those guys are still very young on just focused on doing their own thing. [...] I think differently about it. I like the technology, developed it and share that out of idealism and because I'm a nerd, haha." He says P3 does not act the same way and that's leads to having less discussion."
P1	MM7	02/03/2017	22	RHE	KNOWLEDGE SHARING	As a new impulse to the discussion, EH nudges P1 to consider acting upon the lack of sharing from P3's side. P1 first says that it's okay. He continues, however, by saying "you miss opportunities [...] you'll never come up with new initiatives". EH says, "and that is exactly my point". P1 points he is more about the bigger picture with a focus on innovation and not so much, unlike P3, about checking boxes to obtain and maintain subsidies.
P1	MM7	02/03/2017	22	RHE	KNOWLEDGE SHARING	EH states that those two points of views are not per se in conflict and says that sharing is of importance for the team in order to detect errors and potential faster. P1 agrees that there could be more awareness about detecting potential. He also gives the example that working together on ways to strengthen IP goes without trouble. "There is no fear to share, which is lesson 1", P1 adds. EH says that that way of collaborating needs to become natural for the team. P1 says that the state where people spar freely also has to do with experience. "P3 just graduated". EH says he is not graduated yet and he is aware (RHET nudge). P1 says "that's theory, if you would communicate this to P3 he would agree too. It needs

						to become something natural." EH affirms, "the difference between knowing and doing".
P1	MM7	02/03/2017	22	CRI	KNOWLEDGE SHARING	EH states that those two points of views are not per se in conflict and says that sharing is of importance for the team in order to detect errors and potential faster. P1 agrees that there could be more awareness about detecting potential. He also gives the example that working together on ways to strengthen IP goes without trouble. "There is no fear to share, which is lesson 1", P1 adds. EH says that that way of collaborating needs to become natural for the team. P1 says that the state where people spar freely also has to do with experience. "P3 just graduated". EH says he is not graduated yet and he is aware (RHET nudge). P1 says "that's theory, if you would communicate this to P3 he would agree too. It needs to become something natural." EH affirms, "the difference between knowing and doing".
P1	MM7	02/03/2017	24	RHE	KNOWLEDGE SHARING	Repeat of the nudge at 00:22:18.0. P1 still believes that he should let things take its course. He says that he basically doesn't need anybody and plays the role of being the one to interact and involve people, share IP ideas so [P3] can participate and become IP applicant as well. "That's not very common for people. I invest the team fully so they can reach the same level and give back to others". The communication shows P1's intentions and belief about the purpose of sharing.
P1	MM7	02/03/2017	25	SPS	KNOWLEDGE SHARING	EH genuinely would like to know what's the point in being reluctant to share when you form a company together, which is a corporate marriage. P1 says that's distrust. "The need to keep something up your sleeve in case the collaboration does not work out. That's a point of view one can have", P1 says. EH, maybe naively, says, "Really?!". "That's how 'money breaks things' [Dutch] is defined.", P1 says. EH asks if this was the case with P3 not sharing the test setup. P1 says no but gives another example where P3 was apathetic to share an idea. Eventually, P3 got to a point where he did share his concept. With additions and redesigns from P1, the component now is one of the new IP's. "That's where I want to be. Everybody benefits. Like I have opened up my patent to others as well. You then either have people who understand it and grow or people who don't and stagnate. With P4 it did not turn out well..."
P1	MM7	02/03/2017	29	RHE	KNOWLEDGE SHARING	EH says he is surprised to hear that sharing between Comp A and B can still use an impulse. He says that you (the team) see that it P3 eventually had the idea to share his concept. What made him share it after being reluctant for a while? P1 seems positively triggered and says "Ask him". Seems to be a forced MOD_DLBT? EH compares the communication, once more to that of Comp A with Comp C.
P1	MM7	02/03/2017	30	RHE	KNOWLEDGE SHARING	EH says that sharing ideas/knowledge in an early stage might be a catalyst in R&D processes. He tells P1 that he going to ask P3 if there's any particular reason why he is/has been reluctant to share ideas.
P1	MM7	02/03/2017	31	CYB	KNOWLEDGE SHARING	P1 explains how after the concept of the minimum viable product (P1 says 'most' but that is a mistake) you need develop a vision for a [product] line. P3 had an idea for a, not to disclosed, mechanism that was in line of P1's vision. P3 says he had trouble with getting the dimensions correct. The discussion ceased until a few days ago when P1 told P3 just to send whatever he had. P3 sent is potential IP in the general interest of the company. P1 is wondering if P3 eventually shared his idea because he was aware of the team interests or because he just did what was asked. P1 started to draw yesterday, based on the idea P3 sent him. The result is a new mechanism.

Table 5: P1MM7, KNOWLEDGE SHARING. Communication stage 1, (re)identifying issues, highlighted in yellow. Communication stage 2, (re)developing modulations, highlighted in green.

No modulations were observed in P1MM7 and in P1MM8 (March 14th, 2017) only a minor MOD_DFCT was observed in the 9th minute. Nevertheless, and as mentioned before, P1 has let the EH know on March 21th 2017, via WhatsApp, that the sessions made him reconsider his point of view on the issue: P1 reached out to P3 to initiate a conversation about knowledge sharing and reassured P3 that his input is valued. Although off record, the latter is considered a MOD_DLBRT by P1.

In a similar fashion as Table 5, Table 6 is created using the following filters: **Participant** (P3), **Session** (ALL) and **Issue** (KNOWLEDGE SHARING). Communication stages 1 and 2 are highlighted again in yellow and green again, respectively. The third stage, the assessment of modulations, is highlighted in blue.

Participant	Session	Date	Start time	Code	Issue	Description
P3	MM1	04/10/2016	27	RHE	KNOWLEDGE SHARING	EH asks what P3's role could be in making better team decisions. Big sigh... P3 shares that he feels his influence on the decision-making procedures is limited for he is the most junior member. He feels he can't tell them what to do.
P3	MM1	04/10/2016	27	SPS	KNOWLEDGE SHARING	EH asks what P3's role could be in making better team decisions. Big sigh... P3 shares that he feels his influence on the decision-making procedures is limited for he is the most junior member. He feels he can't tell them what to do.
P3	MM1	04/10/2016	29	RHE	KNOWLEDGE SHARING	EH tries to find out more about the SPS aspect that was shown in the previous section. P3 avoids the question, not sure if that was intentionally, and shares experience on how things usually go.
P3	MM1	04/10/2016	35	RHE	KNOWLEDGE SHARING	Nudging P3 to think about how to get his ideas across. P3 says he personally thinks people are generally reluctant to change. Opposed to earlier discourse he here is sharing a personal opinion instead of just facts.
P3	MM1	04/10/2016	37	RHE	KNOWLEDGE SHARING	EH reframed the question of "what can you personally do?"/"do you see a role...". P3 says he does but adds he doesn't have time since he has to focus on his main task, engineering.
P3	MM2	18/10/2016	16	CRI	KNOWLEDGE SHARING	EH notices how team members do not have the same info to base their decisions on. P3 says it happens quite a bit and that it should be fixed. Plans are made but not always followed.
P3	MM2	18/10/2016	18	CRI	KNOWLEDGE SHARING	Although not disputative per se this expression is the result of some sort of critical communication initiated by EH from previous section. EH now knows the team knows about tantalum and nickel and that P3's distance might have to do with the fact that he is not worried about the weld as much. NOTE; A group session would have cleared up this issue way more effectively.
P3	MM7	08/03/2017	0	CYB	KNOWLEDGE SHARING	Looping in P1MM7 discussion about the lack of knowledge sharing by P3. EH wants to find out why P3 would be reluctant to share and carefully opens up the conversation by sharing his assumptions about the concept of static balancing (SB), based on P1MM7 and nudging P3 to give his version of the story.
P3	MM7	08/03/2017	0	RHE	KNOWLEDGE SHARING	Looping in P1MM7 discussion about the lack of knowledge sharing by P3. EH wants to find out why P3 would be reluctant to share and carefully opens up the conversation by sharing his assumptions about the concept of static balancing (SB), based on P1MM7 and nudging P3 to give his version of the story.
P3	MM7	08/03/2017	2	CYB	KNOWLEDGE SHARING	P3 explaining that the mechanism static balancing was part of his MSc project. The university, among whom P4, decided to not include SB in the project. P3 worked on in on his own dime. P1 brought back the idea of SB. P3 agrees with the decision not to include SB for the 1.0 version but sees it as an add-on for 2.0.
P3	MM7	08/03/2017	5	RHE	KNOWLEDGE SHARING	EH having P3 freely elaborate to get his perspective next to what he already knows. Identifying possible discrepancies -> CYB. RHE is a technique.
P3	MM7	08/03/2017	5	CYB	KNOWLEDGE SHARING	EH having P3 freely elaborate to get his perspective next to what he already knows. Identifying possible discrepancies -> CYB. RHE is a technique.
P3	MM7	08/03/2017	7	MOD_DFCT	KNOWLEDGE SHARING	P3 realizes that the moment of knowledge sharing is an interesting point. P3 also brings forward troubles with drop box being a possible reason for under sharing. P3 calls EH's question a really valid point.
P3	MM7	08/03/2017	8	RHE	KNOWLEDGE SHARING	EH probing P3's reaction to the hypothetical where one might not value their own idea but because of being open to share it, a team member has the opportunity see unseen potential.
P3	MM7	08/03/2017	9	PHE	KNOWLEDGE SHARING	P3 thinking out loud and trying to compare short "standing meetings" (briefings) with sharing early ideas and inspirations. Telling what you are factually doing is easy compared to sharing your thought process.
P3	MM7	08/03/2017	11	RHE	KNOWLEDGE SHARING	Nudging P3 to answer why he finds it difficult to share his thought process. P3 says you can't just share every random thought. That would lead to a blur and would diminish the value of your thoughts. On the other hand, P3 recognizes EH's earlier example of losing potential due to under sharing.
P3	MM7	08/03/2017	12	RHE	KNOWLEDGE SHARING	EH asks if P3 "under shares" because he is afraid (too heavy a word) to come across as stupid. P3 understands the meaning of the questions and agrees to an extent. He adds that it is not fear driven or that P1 makes him feel stupid but that it is rather fed by the aim to impress P1. P3 recognizes P1 as a very accomplished engineer that he looks up to and wants to, therefore, impress.
P3	MM7	08/03/2017	12	SPS	KNOWLEDGE SHARING	EH asks if P3 "under shares" because he is afraid (too heavy a word) to come across as stupid. P3 understands the meaning of the questions and agrees to an extent. He adds that it is not fear driven or that P1 makes him feel stupid but that it is rather fed by the aim to impress P1. P3 recognizes P1 as a very accomplished engineer that he looks up to and wants to, therefore, impress.
P3	MM7	08/03/2017	13	RHE	KNOWLEDGE SHARING	EH sharing a true example of weighing your words more carefully in asking a question to a professor who you consider to be very good in his fields, opposed to a professor who's track record or skill level is less impressive. Coincidentally, the expert professor in the example was the supervisor of P3's MSc research. RHE because, in hindsight, EH seems to want to show P3 that what he experiences is very normal and nothing to be ashamed of.
P3	MM7	08/03/2017	13	PHE	KNOWLEDGE SHARING	EH sharing a true example of weighing your words more carefully in asking a question to a professor who you consider to be very good in his fields, opposed to a professor who's track record or skill level is less impressive. Coincidentally, the expert professor in the example was the supervisor of P3's MSc research. RHE because, in hindsight, EH seems to want to show P3 that what he experiences is very normal and nothing to be ashamed of.

P3	MM7	08/03/2017	15	MOD_RFLX	KNOWLEDGE SHARING	P3 shows reflexivity based on MOD_DFCT earlier this session. The realization of knowledge sharing being an issue in the team has evolved to a heightened awareness of P3's part in under sharing with P4 and the underlying psychosocial reasons that came to the surface thanks to MM. P3 remarks that EH has made a very good observation.
P3	MM8	15/03/2017	2	CYB	KNOWLEDGE SHARING	Looping in the subject of (the lack of) knowledge sharing between P1 and P3.
P3	MM8	15/03/2017	2	RHE	KNOWLEDGE SHARING	EH is chooses words carefully since he suspects the subject at hand is sensitive (P3 not feeling secure enough to share ideas freely with P1). How to move from awareness to action?
P3	MM8	15/03/2017	4	MOD_RFLX	KNOWLEDGE SHARING	P3 says he has thought about knowledge sharing and concludes that there should be no reason to withhold knowledge sharing since all IP will be controlled by one company. P3 started the proceedings with his lawyer and sent all the files to P1
P3	MM8	15/03/2017	6	MOD_RFLX	KNOWLEDGE SHARING	Same nature as previous mod. P3 elaborates that this [situation] is a good exercise to establish a culture where knowledge sharing is the norm.
P3	MM8	15/03/2017	6	CYB	KNOWLEDGE SHARING	EH summing up last session's conclusions to introduce the question "now what can we do about it?".
P3	MM8	15/03/2017	6	RHE	KNOWLEDGE SHARING	EH summing up last session's conclusions to introduce the question "now what can we do about it?".
P3	MM8	15/03/2017	7	MOD_DLBT	KNOWLEDGE SHARING	P3 has since the last session shared all details concerning SB with P1 but, more importantly, he has reached out to P1 for his expertise on IP filing/claims. P3 is less experienced with that so he set up the collaboration between him, P1 and the patent lawyer in Iceland, proactively asking P1 for help and support.
P3	MM8	15/03/2017	9	CYB	KNOWLEDGE SHARING	Rephrasing what P3 said: that being mindful about knowledge sharing is half the battle and that there might not be a generic formula for this issue.
P3	MM8	15/03/2017	12	MOD_DLBT	KNOWLEDGE SHARING	P3 informing EH about his new way of sharing knowledge from now on. His awareness led him to the concept of info-packaging; you don't want to send a package to light (waste) or to heavy (slow, rigid) but jut right so people know what they are supposed to do with the content; either answer a question, think along or take action (own words).
P3	MM8	15/03/2017	15	CRI	KNOWLEDGE SHARING	Discursive reflection on the size and content of these info packages and on how they depend on the person you communicate with; how well do you know each other? What does the person already know? What's important to them specifically (lawyer versus P1)?
P3	MM8	15/03/2017	16	RHE	KNOWLEDGE SHARING	EH asking, now directly unlike he did a 9 min, if P3 sees the modulations as a result of MM. P3 confirms. EH resumes how he and P3 actually went through a cycle in the decision protocol, starting with the problem of under sharing to the challenge of how to package information to share with collaborators.
P3	MM8	15/03/2017	17	CRI	KNOWLEDGE SHARING	EH asks if P3 sees room to apply his new-found awareness in different and future project. As P3 continues he explains that a pitfall for collaboration is to assume that the collaborator knows what you know (P4 presentation as an example). Who am I talking to? What do they know and need to know in order for them to be able to collaborate? If you can't establish that you're not collaborating but you're presenting. If you want to get something but you have to make sure you've given the info needed to collaborate.
P3	MM8	15/03/2017	17	MOD_DFCT	KNOWLEDGE SHARING	EH asks if P3 sees room to apply his new-found awareness in different and future project. As P3 continues he explains that a pitfall for collaboration is to assume that the collaborator knows what you know (P4 presentation as an example). Who am I talking to? What do they know and need to know in order for them to be able to collaborate? If you can't establish that you're not collaborating but you're presenting. If you want to get something, you have to make sure you've given the info needed to collaborate.

Table 6: P3MM1-8, KNOWLEDGE SHARING. Communication stage 1, (re)identifying issues, highlighted in yellow. Communication stage 2, (re)developing modulations, highlighted in green. (Re)assessing modulations, highlighted in blue.

Table 6 demonstrates how and when the issue identification stage goes into modulation development and how, based on the modulation assessment, the EH either steers back to reidentify the issue (when the issue needs to be clearer to the participant e.g.) or redevelop the modulation.

Based on the results from sections 4.1 to 4.5 and the observations made about the communication stages in the current section, the MM Communication Model (MMCM) is hypothesized, as depicted in figure 6.

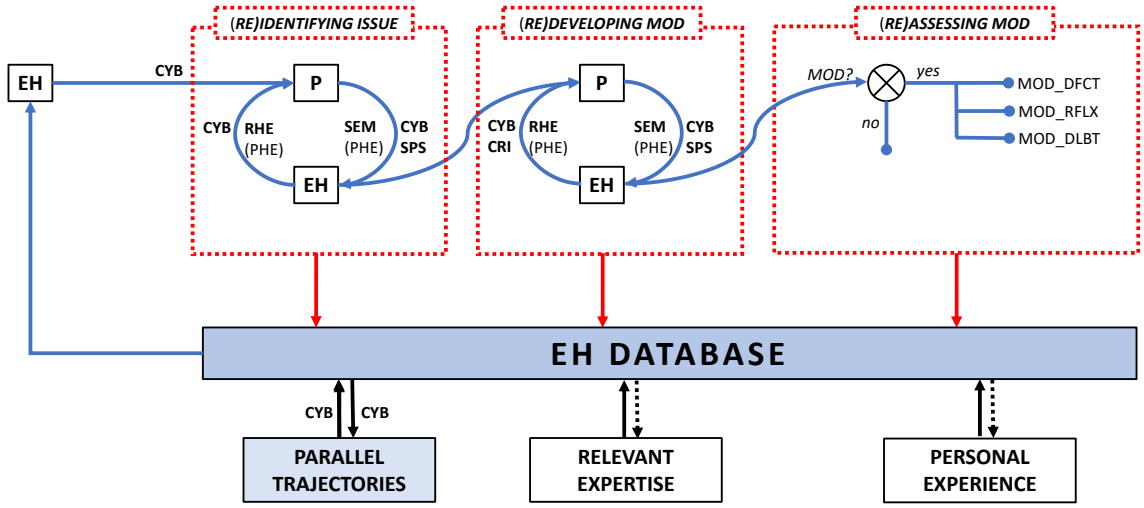


Figure 6: THE MIDSTREAM MODULATION COMMUNICATION MODEL

The model distinguishes the three stages of MM communication, being the *(re)identification* of the issue at hand, the *(re)development* of a modulation and finally the *(re)assessment* of the modulation. The first two stages involve interactions between EH and the participant, described with the communication traditions taken from the essay 'Communication theory as a field' by Robert T. Craig (1999). The third stage of assessing possible modulations is a process that solely involves EH.

The data acquired in each stage is saved to the EH memory, i.e. the EH database. Similarly, the EH database has cybernetic exchanges in the form of data acquired from parallel sessions with participants working in the same project. The EH's expertise, in this case medical technology, and his personal life experiences are internal factors that interact with the EH database. At any point in MM communication, the EH is able to use data from the EH database to (re)identify issues and (re)develop modulation, starting a new cycle. The Excel database structure has been crucial in being able to store and recall the large amounts of data of the four parallel trajectories.

An interesting secondary finding is that the EH's professional expertise, as well as personal experience, is influenced by MM activities, which indicates EHs undergo a learning process simultaneously with the participants.

Focusing on the communication in the first and second stage of the MM process we observe that MM communication is predominantly characterized by the rhetorical and cybernetic tradition. The rhetorical technique of probing and nudging, which is applied by the EH to

frame, direct and accelerate the participants decision-making process, is often alternated with cybernetic activities such as acquiring, linking and redistributing information from and between participants during the course of an MM trajectory. The cybernetic tradition is also observed going the opposite direction where participants provide objective and factual information about their professional activities. This cyclical process resembles a feedback loop, which is a cybernetic principle in its own respect, depicted in the MMCM.

The remaining traditions characterize MM communication as follows. The critical tradition is mainly observed in discursive reflections on considerations for future decisions. The tradition also appears in interactions where EH becomes quite forward in his efforts to establish modulations in the second stage of the MM process.
The socio-psychological tradition characterizes the emotive communication that takes place during MM. In this particular study, most of these expressions are based on a range of feelings such as anger, frustration, fear and indifference. The communication is not always verbal. As mentioned earlier, sighs, huffs or the change in tone may indicate emotive expressions as well.
The phenomenological tradition is observed where the EH and the participant have genuine exchanges of personal experiences. The quantity and quality of phenomenological exchanges appears to indicate the status of the informal relationship between participant and the EH.
The semiotic tradition characterizes communication that is mediated by drawings or sketches as a means to explain and discuss issues. The tradition is also observed in instances where figurative symbols or images are used to explain characteristics of actual matters. Expressions like “it’s as if” or “kind of like”, characterize these observations. Finally, the semiotic tradition is observed when misunderstandings occur about the actual meaning of a concept or a word.
The sociocultural tradition is observed only twice in issue-unspecific communication about the process and boundaries of MM.

5. Conclusion

Given the research problem, the primary goal of this study has been to investigate the characteristics of MM communication, as well as to capture the outcomes of this investigation in a model. For this particular study, the context was defined by a corporate design team developing medical device technology. This context caters to the aforementioned growing attention for the incorporation of SEAs within medical device technology as well as the increasing demand for inclusive design methods. In order to understand and model MM communication, modulations needed to be observed. Therefore, the conditional goal of this research has been to validate MM within the field of medical device technology. Neither the primary goal or the conditional goal had been reached in previous studies.

From the conditional goal followed the research question: *How do the modulations found in this study, if any, compare to modulations found in earlier midstream modulation studies?*

From the primary goal followed the research question: *What are the characteristics of the communication that takes place between embedded humanists and technical experts during midstream modulation?*

5.1 Conditional research question

For each participant, de facto, reflexive and deliberate modulations were observed. The conditional goal of this research is therefore reached. The distribution of the modulations is captured in table 7. P1 to P4 participated in 8, 6, 8 and 6 sessions, respectively.

MODULATIONS PER PARTICIPANT	***MOD_DFCT***	***MOD_RFLX***	***MOD_DLBT***	***Grand Total***
P1	3	7	3	13
P2	1	7	4	12
P3	2	5	2	9
P4	3	8	1	12
Grand Total	**9**	**27**	**10**	**46**

Table 7: MODULATIONS PER PARTICIPANT

The nature of the modulations was as diverse as the issues that arose during the MM trajectory. Modulations were established in how participants communicate, organize and innovate within the project. Modulations within the issue PROFESSIONAL DEVELOPMENT impacted activities of the participants outside of the project as well.

The modulations found in this study compare to modulations found in earlier studies as follows:

Fisher, 2007
The modulations, concerning the issues KNOWLEDGE SHARING and PROTOTYPE in particular, are similar to the modulations found in Erik Fisher's 2007 ethnographic intervention in an academic nanotechnology research group. MOD_RFLX is the most observed modulation. As in Fisher's study, the participants of this study showed self-reflection as well as reconsiderations of materials and mechanisms in regard to the laparoscopic device.

Schuurbiers, 2011
The modulations in this case study do not compare to Schuurbiers' work in the sense that the participants do not seem to have broadened their work with SEAs. The difference can be explained by the fact that the work of medical engineers is very much connected with SEAs by default. For instance, each product needs to comply with the Medical Design Directive. In one of the session, P2 confirms that in the field of medical engineering it is impossible to enter the market successfully without being aware of the societal value and economic impact of your innovation.

Flipse et al., 2013
The issue with the most modulations in this case study is OPERATIONS, which compares seamlessly with the communication and cooperation that Flipse observed as the subjects with the most modulations. The fact that OPERATIONS counts so may modulations may indicate the need for tools to organize innovation processes more effectively.

McTiernan et al., 2016
The modulations of the case study do not particularly compare to the modulations McTiernan and her team observed, which can be explained by the dual role of the EH. In McTiernan's study, the EH was a member of the design team while in this case study, the EH is real outsider. The discussion of where and how MM was to be applied described in the 2016 paper, did (therefore) not take place in this particular case study. Nevertheless, both studies do have in common that EH is an engineer by trade opposed to a 'typical' social scientist. Obviously, this conclusion could have been drawn at the start of this study.

Clearly, the nature of the modulations found in this study compare quite well to some of the modulations found in Fisher (2007) and Flipse et al. (2013). The context in which technical experts operate seems to determine the nature of the modulations observed, as shown in the example of Schuurbiers (2011). The position and role of the EH within a research team can influence the MM process and therefore the nature of its results as well, as shown in the example of McTiernan et al. (2016).

5.2 Primary research question

MM communication is described based on issues (section 4.1), communication traditions (section 4.3) and how the traditions develop during the MM trajectory as well as within a session (sections 4.4 and 4.5, respectively). The answer to the primary research question is captured by the concluding MMCM, hypothesized in section 4.6. MM communication is

characterized by three alternating stages. The first stage, (re)identifying the issue, predominantly consists of short segments in which the EH uses RHE and CYB to identify issues relevant to the participants' tasks. The communication can be mediated by symbols (SEM) and it can show emotive expressions (SPS). Genuine exchanges of (personal) experiences indicate the status of the informal relationship between the EH and the participant. The second stage, (re)developing the modulations, is characterized similarly to the first stage. However, the communication contains discursive reflections and discussions as well (CRI). The third stage, (re)assessing the modulation, is technically not characterizing MM communication but rather the process of MM. The outcomes of each stage are figuratively stored in the EH database. The database, which is partially digitalized in Excel for the purpose of this study, contains data from parallel MM trajectories as well as professional and personal experience. Knowledge from all these data sources combined enables the EH to take conscious actions in the advancement of the MM trajectory.

6. Recommendations

The first recommendation would be to validate the MMCM in other MM studies. The data for the validation of the model can come from new studies or from documented audio from older studies. As expected, the application of Craig's meta-model assured coding possibilities and descriptions with sufficient level of detail to model MM communication. The application of a more detailed theoretical grid is not excluded from future research and should therefore be discussed.

Secondly, further discussion on the method that was used for data processing in this study is recommended. The discussion should also entail the integrative value of the parameter 'issue'. Building a database structure that assists in analyzing communication and decision-making during innovation processes is unique for the field of STIR. Mastering such methods could be especially valuable in non-academic settings where the EH operates as a consultant whose task is to support the decision-making process and the organization of innovation trajectories. Building and maintaining a database structure, allows for on-the-fly monitoring and presentations of any parameter accounted for, which makes it a powerful tool in communicating insights, outcomes and recommendations with clients.

The third and final recommendation is to focus on 'Slipstream Modulation' (SM) in future studies and consultancy trajectories. The impact of R&D decision-making is not only seen in how and by whom technology is used, but also in the socio economic and ethical footprint left behind in its slipstream. The Slipstream consists of practical implications for SEAs that are indirectly caused by R&D decisions. Of course, some of these practical implications, such as resource supply and disposal, are discussed during MM sessions. However, SM is a call for EHs to *explicitly* focus on how to minimize indirect disadvantageous impact of R&D decisions-making regarding SEAs. The focus of MM sessions is determined by more obvious issues regarding technological principles, corporate operations and communication. Making a deliberate distinction between the Midstream and its Slipstream might help EHs as well as participants to organize activities and identify priorities in R&D projects.

7. Literature

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