

BMJ Open Qualitative investigation of trace-based communication: how are traces conceptualised in healthcare teamwork?

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ABSTRACT

Objectives This interview-based qualitative study aims to explore how healthcare providers conceptualise trace-based communication and considers its implications for how teams work. In the biological literature, trace-based communication refers to the non-verbal communication that is achieved by leaving ‘traces’ in the environment and other members sensing them and using them to drive their own behaviour. Trace-based communication is a key component of swarm intelligence and has been described as a critical process that enables superorganisms to coordinate work and collectively adapt. This paper brings awareness to its existence in the context of healthcare teamwork.

Design Interview-based study using Constructivist Grounded Theory methodology.

Setting This study was conducted in multiple team contexts at one of Canada’s largest acute-care teaching hospitals.

Participants 25 clinicians from across professions and disciplines. Specialties included surgery, anesthesiology, psychiatry, internal medicine, geriatrics, neonatology, paramedics, nursing, intensive care, neurology and emergency medicine.

Intervention Not relevant due to the qualitative nature of the study.

Primary and secondary outcome Not relevant due to the qualitative nature of the study.

Results The dataset was analysed using the sensitising concept of ‘traces’ from Swarm Intelligence. This study brought to light novel and unique elements of trace-based communication in the context of healthcare teamwork including focused intentionality, successful versus failed traces and the contextually bounded nature of the responses to traces. While participants initially felt ambivalent about the idea of using traces in their daily teamwork, they provided a variety of examples. Through these examples, participants revealed the multifaceted nature of the purposes of trace-based communication, including promoting efficiency, preventing mistakes and saving face.

Conclusions This study demonstrated that clinicians pervasively use trace-based communication despite differences in opinion as to its implications for teamwork and safety. Other disciplines have taken up traces to promote collective adaptation. This should serve as inspiration to at least start exploring this phenomenon in healthcare.

Strengths and limitations of this study

- The use of Swarm Intelligence as a sensitising framework brought awareness to an alternative form of non-verbal communication.
- This paper offers a novel conceptualisation of trace-based communication in healthcare teamwork.
- Analysis of various examples of traces illustrated the key elements of the definition of a trace: focused intentionality, successful versus failed traces and the contextually bounded nature of the responses.
- As the focus was on providing a definition of a trace, this study did not investigate how trace-based communication is used in combination with verbal communication.
- Sampling clinicians from a variety of specialties offered the opportunity to identify patterns in how traces are conceptualised, but prevented exploring which environments may benefit more than others.

INTRODUCTION

Clear, explicit, verbal communication has been identified as an important marker of effective teamwork. Hence teamwork training in healthcare has tended to prioritise verbal communication over non-verbal communication.¹ In the healthcare literature, non-verbal communication in teamwork has mostly been referred to as body language in the form of gesture, posture, bodily orientation, facial expression, eye contact or physical distance.^{2 3 3–9} While important, research on non-verbal communication in healthcare teamwork has not been as extensive as on verbal communication. For instance, in the context of surgery, some authors have suggested that the lack of in-depth attention to non-verbal communication is related to the tendency of teams to take non-verbal communication for granted.³ Given the limited attention placed on non-verbal communication in the teamwork literature, a paucity of research exists that considers whether other forms of non-verbal communication, beyond body language, might be relevant in healthcare teamwork. Research in biology has identified

a form of non-verbal communication—referred to as trace-based communication—that non-human organisms (such as social insects) use to effectively work together as a collective.¹⁰ Using the analogy of social insects, this paper explores how healthcare providers conceptualise trace-based communication and considers its implications for how teams work.

Communication literature within the field of healthcare recognises the inextricable relationship between non-verbal and verbal communication.^{7 11–13} The communication literature highlights the integral role non-verbal communication plays in the patient–physician encounter. Physician gaze, body posture, hand movements, tone of voice, facial expression and even scrub colour impact how patients perceive their clinical care and the quality of physician’s communication.^{14–18} The interaction between verbal and non-verbal communication is so important to the patient–physician exchange, that many medical educators argue for explicitly training clinicians in this skillset.¹⁹ In healthcare teams, particularly surgery, non-verbal communication enables teams to effectively operate during complex or urgent moments in the surgical encounter. Where one positions their body during a code can help indicate leadership roles⁷ or indicate to a trainee that the surgical staff member wishes to take over the procedure.³ Additionally, non-verbal communication is useful tool in navigating team hierarchies. For example, a nurse raising their eyebrows or a trainee intentionally moving a piece of surgical equipment further from a surgeon’s grasp may act as an important form of ‘speaking up’ that both saves face and avoids conflict.^{2 5 20 21}

According to broader communication theories, non-verbal communication encompasses more than just body language and has been defined as ‘intentional behaviour that is used to symbolically convey an idea’ or ‘everything that we do except the words that we use in our face to face interactions... even our artefacts, the clothes we wear, the rings and jewellery that we carry with us’.²² The use of artefacts is the foundation of trace-based communication. In the biological literature, trace-based communication refers to the non-verbal communication that is achieved by leaving ‘traces’ in the environment and other members sensing them and using them to drive their own behaviour.^{23 24} Trace-based communication is a key component of swam intelligence and has been described as a critical process that enables superorganisms to coordinate work and collectively adapt.²³ Ants, bees, fish colonies and human societies are all examples of superorganisms in nature.²⁵ In the case of ants, they leave pheromones for other ants to smell and know what to do. For humans, leaving your coat on a chair indicates to others that this seat is occupied. While there is room for multiple interpretations (ie, someone forgot their coat), the object was intentionally used to communicate a message to others.

While trace-based communication is gaining traction in other industries, its exploration and use in healthcare

teamwork remain largely unacknowledged. Examples of other industries actively using trace-based communication include the military to improve SEAL (SEa, Air, and Land) team training,²⁶ the construction industry to increase the efficiency in interior wall building,²⁷ and the tech industry to optimise forecasts and decision-making.²⁸ These examples share the same philosophy: without directly talking to each other, individuals become aware of traces left in their work environment and use them to carry out their part of the work. In the case of healthcare, the introduction of electronic health records has opened one avenue for the use of traces such as digital ‘flags’ for asynchronous communication in acute care settings.²⁹ Others are beginning to uncover some versatile non-verbal strategies trainees are using to challenge decisions by their consultants.²¹ For instance, in an intubation emergency, effective cues have included obstructing the consultant, touching the consultant’s shoulder repeatedly, raising their hand, removing the laryngoscope or placing the face mask near the consultant. The first three cues used body language, while the latter two featured traces (ie, objects) to communicate a message. The grouping of these two different forms of non-verbal communication into the same category suggests either lack of awareness or lack of language to discriminate them. These incidental research findings are drawing attention to the presence of trace-based communication in clinical settings. Yet a purposeful exploration of trace-based communication in healthcare teamwork is lacking, and thus its potential to strengthen teamwork remains largely untapped.

This paper explores how trace-based communication is conceptualised by healthcare providers and how it might be harnessed for better team function. Unless alternative forms of non-verbal communication are more systematically understood, it is difficult to determine how to support its place and relevance in healthcare teamwork.

METHODS

Purpose and intention drive all forms of human communications. Understanding how and why someone decides to communicate in a certain way and not another is not easily quantified. It requires an approach to research that promotes direct engagement with the participant that allows participants to make sense of their experiences and that systematically analyses words over numbers.³⁰ Qualitative methodologies constitute such an approach. Out of the variety of qualitative methodologies,³¹ this paper uses Constructivist Grounded Theory (CGT) to explore how trace-based communication is conceptualised by healthcare providers. CGT is a qualitative methodology used to understand the ways in which individuals and groups socially interact, conceptualise, adjust and establish relationships and patterns of behaviour.³²

Since the goal is to explore in-depth and make sense of people’s experiences, qualitative research data consist of lengthy accounts of those experiences that can be obtained with relatively small samples. This study

employed a purposeful sampling strategy.^{33 34} Purposeful sampling involves identifying and selecting individuals that are especially knowledgeable about or experienced with a phenomenon of interest. In selecting these individuals, it is important to consider availability and willingness to participate, and the ability to communicate experiences and opinions in an articulate, expressive and reflective manner. Clinicians from across professions and disciplines were invited to participate in a single, 60 min semistructured interview; 25 individuals consented to be interviewed for this study. Specialties included surgery, anesthesiology, psychiatry, internal medicine, geriatrics, neonatology, paramedics, nursing, intensive care, neurology and emergency medicine. The first author of this paper, who conducted all interviews, is a PhD scientist appointed to a clinical department. As a non-clinician, she does not hold any clinical or supervisory relationship with the participants. An interview guide was constructed at the outset of the study and refined in an iterative fashion as per the principles of CGT. During the piloting of the interview guide, it became evident that participants struggled with some of the language related to trace-based communication and its origins; therefore, the decision was made to provide a succinct and accessible summary of the key ideas for contextual purposes. At the start of the interview, participants read the one-page explanation of key principles of Swarm Intelligence (see online supplemental appendix 1) and the following description of trace-based communication: ‘A key premise in biology states that when organisms act in a common environment they leave traces. Traces are objects, marks or signals that stimulate the performance of a future action by another organism. As such, traces enable a flexible way to support indirect interaction between organisms without adopting dedicated communication channels’. Clinicians were then asked to share examples of traces they have used or have seen others use in their clinical context. Once specific examples were identified, participants shared additional insights around questions such as: How are traces used? What are the intended or unintended messages? What types of situations are they better suited for? Interviews were audio recorded, transcribed verbatim and deidentified by a professional transcription service to protect anonymity. In average, each interview produced 15–20 pages of data for analysis.

Data collection and analysis in CGT requires multiple readings of the dataset using an iterative process—meaning that data collection and analysis occurred simultaneously.³² This step involved both authors. The analytical process unfolded in three progressively interpretive stages as per CGT: initial, focused and theoretical. Initial coding—the first five transcripts were read line by line and coded using gerunds (action words ending in ‘ing’), and participants’ words (in vivo codes) to capture the meanings and actions described by participants. The intention of this first stage of analysis is to describe, rather than interpret, participants’ perspectives and experiences to ensure that preliminary findings are

firmly ‘grounded’ in the data. Focused coding—five more interviews were analysed and compared with the previous five to consolidate initial codes into preliminary themes that were used to focus code the rest of the transcripts. Theoretical coding—a coding framework (see online supplemental appendix 2) was finalised and used to recode the entire dataset. The results of this analytical process were presented to a subgroup of the participants to consider resonance, trustworthiness and transferability, ensuring the rigour of the analysis.³⁵ Throughout this process, iteration and constant comparison, the two key principles of CGT, were central to the analytical approach. Since CGT does not start with an a priori theory, this study used traces as a sensitising concept when engaging in constantly comparing data within and between transcripts. Recruitment was ceased once theoretical sufficiency was achieved,³⁶ meaning that the analysis determined that data categories offered sufficient conceptual depth and complex connections to fulfil the purpose of the study. Throughout the research process, reflective and analytical memos were written to move the findings from descriptive to interpretive to theoretical, and to document the author’s engagement in reflexivity³⁷ (see online supplemental appendix 3).

Patient and public involvement

Patients or the public were not involved in this study.

RESULTS

While participants did not label it as such, using traces for communication was not a foreign concept. Participants described trace-based communication and its elements in the healthcare setting in a variety of complex ways. We used these descriptions to develop a definition of a trace in a human social environment:

A trace is an object (mark, signal) that is intentionally and strategically used to modulate an environment in order to prompt action by another team member. Unlike non-human organisms, humans can interpret traces in different ways, such that the trace may succeed or fail to prompt the intended action, and may have multiple effects. A trace response is social, not biological, and is therefore influenced by time, space and interpersonal relations.

Using excerpts from study participants, the results will elaborate the following elements of the definition of a trace: intentionality, success/failure and response. In order to enhance readability, this section was written using the technique of integrating verbatim quotes from the participants into the description of the results.³⁸ Italicised numbers in brackets represent the codes assigned to participants during the process of anonymisation. These numbers are also provided to comply with the authenticity principle of qualitative research writing.³⁸

Intentionality of a trace

Regardless of the form that traces can take, participants took one of three positions when discussing the

potential intentions behind them: promoting efficiency, preventing mistakes or saving face. In recalling an acute resuscitation, an emergency physician indicated that she felt the urge to position the ultrasound adjacent to the patient's chest to help the leader preserve flow by 'optimising the use of our [the team's] time' (110). Similarly, other participants talked about traces as a vehicle for efficiency, 'when the nurse really wants us to hurry up and get a patient discharged, there will be an ophthalmoscope by the bedside' (113). In the neonatal intensive care unit, checking the eyes is usually something neonatologists do on discharge before a baby is to be transferred out. Conversely, others spoke about using traces to prevent lapses in patient care when they were interrupted by 'leaving all the tools at the bedside so that if the occupational therapist comes along, they will know that now would not be a good time to take them (the patient) away' (103). Yet other participants highlighted the potential of traces to be used 'as a face-saving thing, or a way of avoiding the patient seeing what I am thinking because I am not certain' (110). An example was the case of a paramedic who laid out two sets of equipment for his senior partner to indicate the correct equipment to use without having to verbalise it in front of the patient. This last intention was also recognised as a strategy to deal with 'issues of power and hierarchy to enhance or prevent a message to be communicated' (101). For instance, participants remarked that in teaching environments, 'they (traces) become socially more important when learners need to navigate ways to propose ideas and feel comfortable' (106) speaking their mind. This was particularly prevalent, for example, in settings where trainees rounded patients in multiprofessional teams with various levels of training, such as the clinical teaching units.

Success and failure of a trace

Traces were regarded as successful by participants when they triggered the intended action. For instance, a successful trace such as the 'butterfly, a little magnet or a sticker either on the chart or on the door' was commonly used in a neonatology unit. This trace prompted healthcare providers 'to be sensitive that there has been some loss experienced' (113). Two participants separately recalled feeling 'remarkably uncomfortable when hearing that pitch (the pulse oximeter) goes down (124); it is one of those traces that we reliably use because it is potent' (122) in indicating that a patient is losing oxygen rapidly and prompting the team to quickly reassess and take action. Participants also provided examples of failed traces when they realised the intended action was not achieved. Failed traces were identified as those that took on different meanings mainly due to a lack of attention as to how the evolution of the situation changed people's interpretations. For instance, local hospitals have created a new violence flagging policy where patients are given a purple arm band if they are considered a violence risk. However, with time, the purple arm band became a ubiquitous practice, prompting participants to describe it as

a failed trace because 'we've actually diluted the signal by putting it (purple arm band) on everybody who's ever kind of been verbal or physical in a delirium' (116).

Other participants indicated that a trace also failed when they were ignored as when the intended message conflicted with personal preferences. For instance, in dealing with a colleague who tended to give more narcotics than what she felt necessary, one clinician described her approach of 'intentionally leaving a small syringe on the desk and leaving the rest tucked away in a corner' (117). Her goal was to convey the message that she wanted her colleague to only give so much. Despite her efforts, 'that cue was completely missed because (when) I came back the consultant said there was only so much in the syringe and he took the rest and gave the rest' (117). Another participant reflected that when things get busy, 'they (the consults) all get put back in the slot, so they had been laid out as a sign of, these need to get done, and the next thing I know they are back in the slot' (113) because people do not want to do the non-urgent consults and opt to undo the trace. Regardless of the potential for success or failure, participants also commented on the multiple effects that some traces carry. The most striking example was the purple armband that 'triggers a feeling of helplessness among staff who feel like our patients are being unfairly stigmatised', but who also believed that it should be 'part of workplace safety legislation' (112). Stigma and safety acted as two different effects of the purple arm band despite the original intention. When comparing the instances in which traces succeeded or failed, participants agreed in that it all came down to whether 'the individuals who are looking after that environment are used to understand the implications of it' (122) and able to respond accordingly.

Situational responses to a trace

Traces were described as being contextually bounded by time, space and interpersonal relationships. As participants described, particularly in highly acute situations, traces 'only really have a single meaning for the first 5–10 min' (122). If someone were to appear later, the chances for misinterpretation would increase. And this is because they missed the 'rest of the social interaction between the leader and the team members, (therefore) they are not going to be able to understand in what context it was put there'. As such, 'the power of the trace degrades because its meaning becomes unstable as time progresses and the social context progresses' (110). Another participant described it as the potential for losing the big picture, particularly when traces are left behind unintentionally or are moved to a different space. For instance, if after dealing with a traumatic cardiac arrest, the equipment remained in the resuscitation room and then a new cardiac arrest were to come in, 'it would be harder for the team members who maybe have not been present, who are new to the room, to gather a clear situational awareness of what is going on' (114). They might be left figuring out whether or not the resuscitation has

already taken place likely losing precious time to deal with the acuity of the situation.

Time and space appeared as constraints for some participants. Yet for others, traces offered distinct benefits when comparing them to direct communication protocols. Some participants brought attention to the idea that when people refer to direct communication, they often refer to an interaction between two individuals. Whereas indirect communication using traces was described, in some instances, as being different, in that ‘it is something that actually has a role within an environment’ (125). As this participant illustrated, when someone uses a trace, they are not communicating to a single individual exclusively, ‘they are essentially inserting something into the environment... (to) include very contextualised pieces’ that are not covered by a checklist because ‘the checklist is generic’ (125). An example in anaesthesia was the multiple ways in which an intubation is performed: ‘what (the tools) you use depends on what you are familiar with, but also on patient-related factors... there is nothing in the checklist that focus(es) your attention to what this patient needs’. In their opinion, ‘it is not a failure of the checklist overall, it is a failure of the checklist to meet the needs of a complex situation’ (125). This insight was used to ask subsequent participants to reflect on what other complex situations could be suitable for trace-based communication. They articulated four other: (1) emotionally consuming situations ‘as in the labour and delivery ward, if there is a butterfly you don’t go in and say congratulations, because you know there was a loss’ (113); (2) low stakes situations that involve training where ‘I may just kind of nudge the anaesthetic gel towards her... to kind of make them realise that they have forgotten it’ (117); (3) situations where the core team is stable as in ‘geriatric rehabilitation unit (where) it is much easier because everybody has worked with each other for some time’ (118) and finally, (4) asynchronous situations such as when nurses prepare an operating room while the surgeon is in the wards and ‘if nurses have concerns, they will leave the bedside chart in the room open’ (119) to alert surgeons that something requires close attention. While a trace ‘is probably most significant in the moment that it is used and then becomes less significant’ (122), the same participant reflected on the idea that we should not discard traces outright because they have the capacity to flag the ‘ways in which such environment changes’ (122) as they are influenced by time, space and interpersonal relationships.

An additional insight: hesitation while describing the use of traces

Participants were hesitant and cautious when they described situations where they chose traces over verbal communication. Early in the interview process, the ambivalence that most participants experienced when recalling examples of traces was noticeable. When asked about it, they wondered if the reason why healthcare providers do not readily appreciate the benefits of traces is because ‘our

training is that you should never rely on indirect communication’ (117). In their accounts, participants tended to add a cautionary note because ‘I think we are really very much explicit communicators... we are almost engrained to not do anything that could be misinterpreted’ (106). While this cautionary sense was not present in all interviews, the pervasive sense was that healthcare providers have been dissuaded from using non-verbal communication because of the assumption that ‘indirect is most likely to get us into trouble’ (103). This was an assumption that remained critically unquestioned by participants.

DISCUSSION

This study showed that while not fully endorsed, traces are pervasively used by healthcare professionals. Even though they are trained and prefer to use verbal communication, examples of traces abounded in this study. This disjuncture between preference and practice suggests that clinicians may have a blind spot for trace-based communication which might prompt them to discard it. However, discarding trace-based communication uncritically might be more dangerous than explicitly considering its pros and cons. Rather, acknowledging when it might be productive could contribute to the safety conversation in ways we have not considered. For instance, the operating room is an environment where non-verbal communication in the form of body language has found a productive place to balance urgency with patient care.³ Yet, non-verbal communication in the form of traces has not been identified or discussed in this environment. In fact, the few studies in healthcare that have hinted at trace-based communication have serendipitously arrived at it. In their exploration about barriers to speak up in anaesthesia, Beament and Mercer found participants using non-verbal challenges to complement high-grade verbal challenges.²¹ Within the repertoire of non-verbal challenges, trace-based communication to prevent further intubation took place in the form of removing the laryngoscope or placing the facemask in a particular place. The laryngoscope and the mask were used intentionally to gain someone’s attention. While Beament and Mercer did not provide a particular discussion about the use of traces, they noted the need for further research. This study adds to this nascent conversation, demonstrating that trace-based communication constitutes another form of indirect communication used by healthcare providers. It further suggests that trace-based communication might prove beneficial for safety by improving healthcare teams’ ability to collectively adapt.

Given the intentionality ascribed to traces, traces carry symbolic meaning.¹³ The practical use of traces within a given social context (eg, operating rooms, intensive care units, clinical wards, etc) create meanings that can be shared by others. This is referred to as intersubjectivity.³⁹ Some of the participants described traces, such as the butterfly, that had become somewhat standardised within their contexts. This standardisation seemed particularly



important for coordinating activities. As elaborated by participants, the butterfly trace created a symbolic repertoire¹³ in the form of a behavioural routine that all members of the team abided by. While a key advantage of creating this kind of symbolic repertoire is to support explicit communication, team members need to remain attuned to counteracting its potential risks. For instance, when new team members join, they should be explicitly trained to use the symbolic repertoire in order to prevent unintentional mistakes when the team needs to rely on non-verbal communication. Training for identification of traces and their assigned meaning might constitute an important effort in improving a team's ability to effectively communicate.

By studying trace-based communication in a human social context such as healthcare teamwork, this study also elaborated the construct of a trace. Focused intentionality, successful versus failed traces and the contextually bounded nature of the responses to traces (time, space and interpersonal relationships) were brought to light in this novel conceptualisation. The literature on trace-based communication in non-healthcare contexts has focused on its applications. Little conceptual work has been done to deconstruct the unique features of traces as they are used in human contexts. Tummolini and Castelfranchi's⁴⁰ work emerged as likely the first and only attempt thus far. Their main contribution is a taxonomy of basic messages that can be communicated when using traces in daily social life. Those basic messages were classified around seven purposes: informing about presence, intention, opportunity for action, action accomplished, goal or result. The authors further suggest that while basic, these messages can be combined into complex behavioural messages, such as using a trace to deliver multiple messages. Although offered as a conceptual framework without empirical evidence, their work contains useful language about the general uses of a trace by humans.⁴⁰ To add to this body of literature, the present study uncovered two key intentions in the use of traces in the context of healthcare: promoting efficiency and preventing mistakes. Tummolini and Castelfranchi also asserted that given our human nature, different meanings can coexist in the same trace. To advance this notion, participants in the present study elaborated further to illustrate how traces succeed or fail depending on whether or not the triggered response takes place within certain temporal, spatial and social conditions. In the absence of extensive conceptual work and the recent calls for more nuanced characterisations,²³ the empirical evidence provided by the present study speaks to the theoretical conversations of what traces are and how they are being used and responded to in relation to the context.

From a practical perspective, participants in this study acknowledged using trace-based communication, yet they expressed hesitance and provided several cautionary tales. Other industries have moved past the hesitancy to embrace the usefulness of trace-based communication. The military offers the best example.⁴¹ As in the present

study, the military has discovered that trace-based communication is useful in some situations and not others. For instance, in ambush situations where safety is paramount because of the asynchronous nature of work, groups of Navy SEALs are currently trained to be attuned to how other team members' actions modify the environment. In a similar way, in this study participants found trace-based communication particularly useful in high-stakes asynchronous situations; they also identified a range of other situations where trace-based communication might be useful, including training situations, emotionally heightened situations and situations where team instability was not a threat. As one might anticipate, not all situations are amenable for trace-based communication. In the military, trace-based communication is avoided in briefing/debriefing situations.^{41 42} The same should be expected in healthcare, for instance in contexts such as trauma, where post-mortem conversations are deemed essential for teamwork.

Whether pervasive or not, this study showed that traces might play a key role in the ability of teams to maintain situational awareness. As illustrated by participants' examples, traces afford the ability to anticipate the leader's and team's needs without disrupting flow. Therefore, a practical recommendation from this study is that healthcare providers engage in simulation training and debriefing conversations that explicitly examine moments in which team members have used a trace to convey a message. By bringing trace-based communication to the surface of those conversations, it is possible to clarify intentionality and uncover patterns of behaviour towards improving team situational awareness. Furthermore, as others have suggested, simulation training offers the opportunity to combine both verbal and non-verbal communication, including trace-based communication, in patient safety scenarios.⁷

LIMITATIONS

As with any empirical study, the findings presented here are bound by research design decisions that draw attention to certain aspects and deflect attention from others. For instance, the decision to sample clinicians from a variety of specialties offered the opportunity to identify patterns in how traces are used in clinical environments but prevented exploring in detail which environments may benefit more than others. Future work could explore the organisational and cultural characteristics of particular clinical environments that influence a trace's success or failure.

While this paper treated non-verbal communication as a separate entity to bring awareness to forms of non-verbal communication other than body language, it is important to note that that verbal and non-verbal communication go hand in hand as communication theory has argued.^{11 12} Therefore, further research is needed to investigate how trace-based communication is used in combination with verbal communication and their influences on how teams work. A context where this exploration might be highly

relevant is interprofessional teamwork communication (eg, communication between surgery and anaesthesia teams). Using the definition offered in this study, methods such as field observations and simulation, in addition to interviews, would add valuable insights into how multiple teams use and respond to traces.

Finally, this paper focused on providing a general definition of a trace and consequently, other aspects were not elaborated, such as how traces are created or categorised. For instance, some participants suggested certain traces as being institutionally sanctioned and others as being created informally out of their personal intentions. While such distinction was outside the focus of this paper, it will be important to consider in future research in order to better understand how and why the way traces are created modulate and influence communication dynamics among team members and across teams.

CONCLUSION

This study has demonstrated that trace-based communication is pervasive in clinical work, but that its conceptualisation had been largely ignored. As such, this study was also intended to plant a seed to at least begin the conversation around trace-based communication. Because unless we take the time to explore it more systematically, we will not be able to decide whether it has any place in our efforts to enhance teamwork and communication for safety.

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Contributors SC designed the study, collected the data and led the writing of the manuscript. Both SC and EF conducted data analysis and EF further participated in writing for the revised manuscript.

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Appendix 1 – Prompt for interview

The way humans work these days is rapidly becoming more self-organized; in other words, less centralized and more interconnected. To understand how that happens, in healthcare we have relied on complexity theory and systems thinking to say things like *in order to improve teamwork, we need to move beyond the focus on the individuals and pay more attention to the interactions among individuals*. However I am not sure we have spent enough time/effort talking about what those interactions look like & their implications. I have found that analogies from biology might provide us with a more concrete way to look at interactions; in particular social insects – the reason being that insects live in colonies and focus on carrying out work together – much in the same way as humans do teamwork!

In a nutshell, social insects behave as a **self-organizing complex adaptive system** with 3 levels: individual, collective/colony, and environment. The way insects carry out work has been called **Swarm Intelligence** and is receiving increasing attention in other disciplines to support human problem-solving. Using swarm intelligence, a solution to a problem emerges as a result of the collective action of the members who interact using two key principles of communication: **solidarity** (direct) and **stigmergy** (indirect). To not get bogged down with terminology, in simple terms, solidarity is the direct member-to-member communication in the local context. If we take the example of ants, the direct member-to-member interaction happens via touch of the antennae; while for humans, our most direct form of interaction happens via language. On the other hand, stigmergy refers to the indirect communication that is achieved by individual members leaving “traces” in the environment and other members sensing them and using them to drive their own behaviour. In the case of ants, they leave pheromones for other ants to smell and know what to do. For humans, a simple example would be when someone leaves a coat on a seat at a theatre. Without saying anything, the coat (i.e., the trace) communicates anyone approaching the seat that it is already taken and that you should look for another seat. Another simple example in regular life would be something like leaving dishes in the sink for your kids to clean. Whether they do it or not, the message is the same “to execute the action of cleaning the dishes”.

While we humans privilege the direct forms of interaction, I am beginning to wonder about the influence of the indirect forms in how we work as part of a team. Therefore, I am curious to learn from your clinical/professional experience to see if we can identify **examples of traces** (like the coat in the theatre or the dishes in the sink) that people use to signal another person that something needs to be done (e.g., don’t sit on this chair or clean the dishes).

Appendix 2 – Sample of Coding Framework

August 19, 2019 – Consolidated coding framework

Type

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|----------------------------|
| Institutionally-sanctioned |
| Informally-created |

Forms

| |
|--|
| successful |
| failed |
| ignored |
| double-barreled (eg., stigma vs. safety) |
| Left over |

Purpose

| |
|---|
| Training (differentiate traces purposefully used for simulation training vs. traces used in actual clinical environments?) |
| Saving face |
| Avoiding conflict or discomfort |
| Promoting efficiency: <ul style="list-style-type: none"> • Getting someone to do something they might have missed or that needs to be done quickly • Anticipate the needs of the team • Manage team's flow and efficiency • Directing attention to something that might be overlooked |
| Preventing mistakes: <ul style="list-style-type: none"> • Override another person's intentions • Signaling "I'm about to do something" or "I'm coming back" • Signaling how you want things to be done / how to proceed • Reminding not to forget something |
| Calling for attention (patients) or avoiding attention (trainees) |

Social life of a trace:

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| Regardless of the form that the trace takes, the effect remains |
| Dilution |
| Timing |

Interpretations and/or responses to traces: **strategies**

Features of a trace:

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| Inferring the other person is on the same page |
| Being explicit and visible |
| Timing and sequencing |
| Assumptions rooted in hierarchy can make a trace fail |
| Unsuccessful because the design is too similar to other objects |
| Traces can be undone |

Suitable situations

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|---|
| High-stakes where multiple people are working simultaneously |
| No time for conversation |
| Low stakes where the core team is stable and few members rotate |
| Emotionally consuming |
| Asynchronous work [patient chart on OR bed, antenatal consults] |
| Handover |

Potential applications of trace-based communication

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| Improving system situational awareness without interrupting flow |
| Navigating hierarchy |
| Overcoming barriers |
| Teamwork training |

July 22, 2019 – Coding and analytical observations (8 coded out of 19)Updated coding structure:

Effect

| | |
|------------------------------------|---|
| successful | <p>The purple armband. It's violence flagging policy in the hospital where if a patient is deemed a violence risk, they're flagged physically by wearing a purple wristband. (112)</p> <p>[restrains left on the bed of a patient to indicate the patient might be violent or confused and might need to be restrained – from Jenny's interview (118)]</p> |
| failed | <p>The case of 'can't intubate, can't ventilate' of Elaine Bromiley, a well-known emergency in anaesthesia: <i>The standard procedure in such situations is a tracheostomy/cricothyrotomy followed by admission to ICU—yet the team of surgical and anaesthetic doctors managing the patient did not execute this option, despite the nursing staff identifying that it was the right thing to do and going as far as booking an ICU bed and bringing the equipment tray into the OR</i> [Bromiley 2015, BMJ Quality & Safety Viewpoint]</p> |
| ignored | <p>At our front desk in the NICU, there is a slot for antenatal consults. So, this is the obstetrician is asking us to come and do a consult for moms who are expected to have a baby with some kind of problem. And usually they are not urgent because the super urgent ones they will call us and say, you have got to come right now. But for the not urgent ones, they get put in this slot. But sometimes, especially if it's busy and people don't want to do the consults, they can get ignored or forgotten. (113)</p> |
| double-barreled: stigma vs. safety | <p>When someone is wearing a band at an appointment, how confidential it is what their history is based on that. It's lost the meaning that was intended because the symbol has become a symbol of stigma, and a symbol that triggers a feeling of helplessness amongst staff who feel like they're, for example, in mental health our patients are being unfairly stigmatised. [On the other hand], there are very small minority of people who have no problems with this because they believe as part of workplace safety legislation, anybody who presents with any sort of violence risk ever should be flagged with a hospital environment. That opinion isn't consistent with human rights legislation and best practice, but there is an interpretation of the purple armband as a necessary flag for workplace safety in a minority of people. (112)</p> |
| undone | <p>But sometimes, especially if it's busy and people don't want to do the consults, I have even seen them all get put back in the</p> |

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| | slot, so they had been laid out as a sign of, these need to get done, and the next thing I know they are back in the slot because they don't have time and they don't want them to get lost. So, that cue or that message that was supposed to be sent when they were laid out has just been undone and put back. (113) |
| Expiration (not sure it belongs here!) | I think that that particular trace [the purple armband], the way that it was implemented, may end, but that there will always be traces in terms of flags because there is a systematic way of flagging patients who might be at risk of violence. I think that general trace maybe won't go away. (112) |

Purpose

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| Training (differentiate traces purposefully used for simulation training vs. traces used in actual clinical environments?) | <p>With learners for sure. So, you presume they've set everything up, they start to do some procedure, and you realize that they are missing a key component, or something that you think is important to be there. So, just while they're carrying on, you don't say, well, go and get it. You do it for them. Usually, the message is you forgot something. You should have had this there (106)</p> <p>In a lot of simulation, if I think about it, we spend our time creating traces. Let's say I want someone to learn about anaphylaxis. Well, I don't announce this is anaphylaxis. I create a case where I pick the three hallmark features of an anaphylactic reaction under anaesthesia, and I create that scenario. By the time you have one, two, or three of those traces, you ought to be down to a diagnosis and then enact a management plan. (106)</p> <p>Well, simulation is all about not overtly dumping a message. It's about subtly creating a clinical scenario, but has all the uncertainty of a clinical scenario and adding in traces to it that would help people sort that out, and seeing if they could do it. (106)</p> <p>Well, some of the stuff around the airway equipment. I won't tell them I'm doing this. I'll just throw the pieces of equipment onto the anaesthetic machine beside them. They'll see it there and usually, they'll go oh, yeah, I forgot to grab that. Yeah, you did. (106)</p> |
| Saving face | So, if there is a team leader who is physician and I'm a non-physician, sometimes either as a face-saving thing, or a way of abbreviating communications so that you don't have to interrupt the team's flow, or a way of avoiding the patient seeing what I'm |

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| | <p>thinking because I'm not certain. Then I might hold a piece of equipment to signal to the physician that I think we're going to need this, and give the physician or the team leader the opportunity to think do we want to do this? A lot of times, they will look at you and say, excellent. I think it's a very good idea we perform that ultrasound. Or I think putting a pelvic binder on this patient is, in fact, a very good idea. Thank you for getting that started. You don't say anything. You just have to pick it up or shift it over into their view. That would be a form of communication that I think happens very often (110)</p> |
| <p>Avoiding conflict or discomfort</p> | <p>When families are uncomfortable with the situation. Let's say they know there may be bad news and they don't want to be around for that, I will find that they avoid us, so they are often not present, they are not there. (113)</p> <p>And sometimes our trainees may do the same thing, so if we find they don't really want to do a task because they are uncomfortable with it for whatever reason, there is a lack of a trace, like they are gone. They make themselves busy with something else, so they are not available to do the task that they don't want to do. And sometimes that task is talking to parents who are deemed as being difficult parents. (113)</p> |
| <p>Getting someone to do something they might have missed or that needs to be done quickly</p> | <p>When it's really busy and we have a patient to be discharged and the nurse really wants us to hurry up and get a patient discharged, you will see that there will be an ophthalmoscope by the bedside. And the reason for this is that we know that the ophthalmoscope to look into the eyes to make sure there are no problems is usually something we do upon discharge for a full physical exam before a baby is to be transferred out. And especially if we are tight for beds or they want to get the process going, they would have pre-emptively gotten the ophthalmoscope out. And if it's sitting there on the table beside the bed you know the nurse is saying, hurry up and do the physical exam because we have got to go. (113)</p> <p>But for the not urgent ones [antenatal consults], they get put in this slot. And sometimes if the unit is really busy, people forget to look in that slot and they build up. So, when they see a giant pile there, sometimes people don't want to do it because it's like, oh my goodness there are so many I have to do. Sometimes you will see people take them out of the slot and lay them out on the front desk, so they are all visible, and that's an indication of, look how many there are, everyone has got to do a few, pull your weight and do some. (113)</p> |

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| | <p>I guess going back to the discussion around the attending paramedic and the assisting paramedic, the attending paramedic might decide that the patient needs a blood glucose collected. So, if they perceive that the assisting paramedic hasn't already perceived that, the attending might reach into the bag, pick up the blood glucometer, and just set it out beside the cardiac monitor as a sign that while you're collecting vitals, please also get a blood glucose. (110)</p> <p>And you see how they [pathology assistants] are very eager and sometimes they're moving the tray a little bit this way or whatever, and you know that they want to remind the resident, show the adrenals, that kind of thing. (109)</p> |
| Override another person's intentions | <p>A good example would be if the assisting paramedic were more senior and more intuitive about what the patient's needs were, and the junior paramedic was not quite as intuitive, the assisting paramedic would go out to the truck and bring in the extrication device they wanted to use. The best example of that is a chair. We have a chair that folds out, and you can carry people out on it. The senior paramedic might do that in order to override any thinking the junior partner might have that the patient would walk out of the house on their own, right? So, sometimes in order to force your partner's hand, you will take initiative and perform something on your own without communicating that. (110)</p> |
| Anticipate the needs of the team | <p>A lot of times, because of the shared understanding of tasks between both members of the crew because they will both occupy that role, they're able to anticipate the needs of the team... So, me unzipping my bag and starting to pull out I.V. supplies is a symbol to them that I am intending to start an I.V. and they will start performing tasks to facilitate that. They would pull out an I.V. bag, and they would hook up the I.V. tubing, and prepare that line for me. (110)</p> |
| Signaling "I'm about to do something" or "I'm coming back" | <p>A lot of times then I will need to leave the room with the intention of coming back. The reason for that is something like, my computer is out in the truck, or I need to go and get cleaned up, or need to assist my partner with something, or collect data from the defibrillator. In that circumstance there, I would often leave my clipboard with my information on it there as a sign that I'm coming back. (110)</p> <p>If I'm seeing a patient, and doing a consult on them, and get interrupted by a page, I might leave all my tools there at the bedside so that if the occupational therapist comes along, they'll</p> |

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| | <p>know that now would not be a good time to take them away. (103)</p> |
| <p>Manage team's flow and efficiency</p> | <p>If you're not the team leader, then a lot of times you don't want to interrupt the communication patterns of the team. If you have a critical observation, but I think a lot of times, people because of hierarchy are afraid to even communicate critical findings so even then they won't do things. The Elaine Bromiley Case. It happened with an elective procedure down in Australia where multiple people attempted intubations on what should have been a straightforward intubation, but it wasn't. She died of a hypoxic brain injury. Meanwhile, people who were standing around were not explicitly saying there was a safety hazard, but implicitly suggesting it by oh, I'm going to move this into this room. (110)</p> <p>But maybe there are some circumstances where that's either impractical or actually slows things down, in which case, I think we should probably be thoughtful about what is our indirect signalling actually doing? An old school example used to be when we didn't use electronic charts and you used paper charts. Every time an order was written, you'd put the chart in sideways and pull a little tab on it so that the nurse would be able to see that a new order had been written since last time, and they would see the chart. Any time a chart would appear with a new order then you knew they were going to process it rather than just putting the chart back in and having it be possible that someone wouldn't notice it for hours. (103)</p> |
| <p>Directing attention to something that might be overlooked</p> | <p>If there is a dangerous family, the nurse often wears the panic alarm clip. So, if we see a nurse with it, it looks like a little button, with a green button on it, and if we see a nurse wearing that on her, usually it's very visible on her lanyard or something like that, then we know that she has probably been assigned to a patient with parents who are difficult. (113)</p> <p>This is a big thing because in medicine, we're all trained to be leaders. We're all expected to be leaders, but how often are you actually in a leadership role? One of the ways that we deal with our situational awareness during a resuscitation is to try and process it in such a way that we anticipate the leader's needs, the team's needs, and prepare for it. That has the double benefit of either increasing the team's efficiency by just getting things prepared for when the leader orders it or drawing the leader's attention to something that they might be overlooking. (110)</p> |

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| | <p>So, a patient has a head trauma, and a team member goes and gets a cervical collar to communicate to the leader that there might be a cervical injury rather than explicitly saying I'm concerned about this potential cervical injury. Or if in a resuscitation the team is concerned that the leader is missing the potential for a pneumothorax or a pericardial tamponade, going and getting the ultrasound machine and putting it adjacent to the chest before going and getting a chest tube and preparing it. Those would be ways that a team would communicate to a leader that I think we need to do one of these things, and maybe you need to consider that a little bit more readily. (110)</p> |
| Signaling how you want things to be done / how to proceed | <p>One example would be if there is a twin pregnancy and one baby has died, so one twin has died, they usually put a butterfly, like a little magnet or a sticker or butterfly either on the chart or on the door. And whenever we see a butterfly we recognise that there is basically some kind of loss there. And everyone walking by would know to be sensitive that there has been some loss experienced. (113)</p> <p>The purple armband. It's violence flagging policy in the hospital where if a patient is deemed a violence risk, they're flagged physically by wearing a purple wristband. So, yeah, that is a physical example of something that's a trigger for action because it's supposed to be a visual indicator to protect people by being aware that a patient might be a risk. (112)</p> <p>There's usually a little table where the nurse has the prep and some towels, so I'll pick out the tourniquet and lay it on the table. So, I'm signalling this is the one I want you to use. I don't tell them. Then, sometimes I'll pick out the clamps for the table or the equipment for the table and I'll lay it down next to the table as, these are the ones we're going to use. But, I don't tell anybody. (111)</p> |

Interpretations and/or responses to traces – **additional code**

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| Strategies | <p>It [parents' absence] signals to me that if they are feeling like this about it we have to give them the news in small chunks that they might feel really overwhelmed by everything that is happening. We may need to employ more of a multidisciplinary team, so just to make sure even for conversations where normally I would have one on one with the parents, that we invite a social worker to be there. If they have a nurse that they are more comfortable with, invite her to be there to try to make the environment a bit more conducive. I would try to call them</p> |
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| | and say, at your convenience, when do you want to sit down and have a chat? And schedule it, maybe if it's scheduled they don't feel like they're just caught. (113) |
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Features of a successful trace

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| Inferring the other person is on the same page | I think traces depend on you being on the same page to begin with, like, you're inferring that the partner knows what's going on. Often, if you don't infer that, then you're going to be very explicit in your communication about what the plan is. (110) |
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Suitable situations

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| High-stakes where multiple people are working simultaneously | <p>I think we use them all the time but we don't know, we have never explicitly called it, these are traces. If you were to ask me to label it, not knowing anything about your study, I would say this is just part of the teamwork, part of the way we communicate collaboratively and unspoken ways that we have a common understanding of. Especially in the high intensity situations. (113)</p> <p>If we're talking about high stakes, then a cardiac arrest resuscitation or a traumatic arrest resuscitation would be the perfect example or pre-arrest circumstances. Very rarely on those teams do you see a whole lot of communication going back and forth because they're able to just create a stepwise pattern of objectives in their mind and just leapfrog over one another to get the task done. (110)</p> |
| No time for conversation | <p>I think the implicit communication is really quite common. Between crews, there are a series of tasks that need to be done over the course of, say, 10 minutes on a call. (110)</p> <p>You presume they've [trainees] set everything up, they start to do some procedure, and you realize that they are missing a key component, or something that you think is important to be there. So, just while they're carrying on, you don't say, well, go and get it. You do it for them. (106)</p> |
| Low stakes where the core team is stable and few members rotate | [the geriatric unit in Parkwood vs. geriatric ACE unit – quote from Jenny (118)] |
| Emotionally consuming | So, when you want to go and talk to them [parents] they have left. They come in very briefly to drop off milk, for example, but they know what time you are there for rounds and they are purposely not there. So, it is a lack of a trace, and that often |

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| | <p>implies to us that they really don't want to talk to us, they don't want an update because they feel anxious about it. (113)</p> <p>But maybe there are some circumstances where that's either impractical or actually slows things down, in which case, I think we should probably be thoughtful about what is our indirect signalling actually doing? An old school example used to be when we didn't use electronic charts and you used paper charts. Every time an order was written, you'd put the chart in sideways and pull a little tab on it so that the nurse would be able to see that a new order had been written since last time, and they would see the chart. Any time a chart would appear with a new order then you knew they were going to process it rather than just putting the chart back in and having it be possible that someone wouldn't notice it for hours. (103)</p> |
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Potential applications of indirect communication – **additional code**

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| Improving team situational awareness without interrupting flow | Or if in a resuscitation the team is concerned that the leader is missing the potential for a pneumothorax or a pericardial tamponade, going and getting the ultrasound machine and putting it adjacent to the chest before going and getting a chest tube and preparing it. Those would be ways that a team would communicate to a leader that I think we need to do one of these things, and maybe you need to consider that a little bit more readily. (110) |
| Overcoming hierarchy | To manage flow and efficiency because communication requires a lot of energy and takes a lot of time, and it cannot be undone. If I move the ultrasound over and it never gets used, then it just gets up back, and that optimizes the use of my time because I'm no longer standing waiting to be told to do something. I'm going we might need this. I think there is an 80% chance we're going to need this so I'm going to move it over, drop, and then have the duplicate purpose of improving efficiency. But also overcoming hierarchy and suggesting to the team leader either because of toxic hierarchy or just cognitive burden on the leader that we probably need to consider this. (110) |
| Overcoming barriers | I think there are probably a lot here, especially with the stigmergy, where you're going to see people using it as a means to overcome barriers, like, cultural barriers. (110) |
| Teamwork training | And I was wondering if, for training purposes, making this kind of phenomenon explicit would help people to understand how to work in teams or to do something about working in teams. Especially if you are new to the team and you come from a different culture. If you come from a culture, for example, where |

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| | the physician is the boss, it's all about the physician, completely patriarchal hierarchical system, then you might lose out on some of these unspoken, tacit communications that we have as a team. (113) |
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Appendix 3 – Sample of analytical memo

July 25th, 2019 – analytical memos

- Methodology section: the analysis started with the sensitizing concept of “trace”, here is how it is defined in the literature. Within the first round of analysis, we realized that that definition was not going to capture what we were seeing, here is what we added and then based on a more fulsome analysis of the entire data set, and here is the refined.
- Shadow-like traces (instead of left over?): the physical trace is gone but the shadow of the intent remains (purple armband, butterfly)
- Purple armband teaches something important about purpose. A physical trace embodies a purpose but that purpose can come back as another physical trace. You don't always need the same physical trace. A purpose can manifest in other physical traces. Relevant for when you want to retain the purpose but deflect some of the symbolism of the physical trace that became problematic. For example, in the future we might not want to use the purple armband to flag violent patients because that physical trace took on a whole different meaning like patient objectification; instead use the exclamation mark by the door as opposed to put something on the patient.
- To consider... instead of “absence of people” as a trace, maybe label the trace as “change in routine” (families leaving the unit to avoid receiving news, family members standing outside the room vs. inside)
- There seems to be two types: institutionally-sanctioned or formal traces (things we, as an institution, agreed with) and personal or informal traces (things individual people tend to do). It seems that the institutional ones are good to have but less exciting. Do I have personal examples that makes people go, we do that, oh my god why do we do that? What are the unintended consequences of doing that? For the next few interviews, pick a few that get people thinking that way and see what people have to say about it.
- Are there other types of traces than formal and informal?
- Note the contrast of the kinds of situations that people talk about: stable teams vs. high stakes situations
- Relationship between purpose and situation: leaving the patient chart on the bed is efficient because it allows for communicating during asynchronous situations (the nurse doesn't have to be there). Also, putting the medication on the anesthesia tray is for saving face during synchronous situations.
- We need to discuss the theoretical importance of the potential for left over traces given the fact that people guard against that possibility (restrains in the geriatric unit and the physician saying that it is not possible because it would be a huge mistake, hence there are things in place that prevent that from happening). Consider it to be an important part of the definition.

- For the story, I probably need an anecdote similar to Jennifer Clasen's paper. Pick a couple of examples that have safety implications and ask people to think about their effects – that might be a way to find that anecdote!
- For the introduction (BMJ safety): after the P/G/H paragraph, I might need to write a paragraph about the direct communication protocols and how popular they have become. Then a paragraph to say something like “but we understand there is a lot of complexity around these protocols because yes, there are direct communication protocols, but people still do all this other stuff, which sort of confounds the effect of the direct protocols; which might indicate that people are not taking those protocols in the way they were intended to. But more importantly, we haven't looked at the indirect communication systematically to ask the question of what purpose does it serve? What patterns does it have? We can then say, indirect communication is not only unavoidable, but it is also profoundly interfering with our direct protocol interventions, which is where we put 90% of our attention in communication interventions in patient safety. I am neither for nor against indirect communication, but unless we understand it much more systematically than what we do now, we cannot decide either what's its relationship to direct protocols or how to support the good stuff in the indirect and tease out the problematic stuff”. Frame the first paper as we know that this part of the communicative landscape, other disciplines/settings (SI in other contexts) have taken it quite seriously and seen how productive and influential it can be, we should use that to at least start exploring what is this phenomenon in healthcare.

June 13, 2019 – analytical memos

- The purple arm band example raises the question of when a person bears the indirect communication of someone else. That's the debacle of the purple arm controversy because the patients don't want to send that message about themselves, they resist that message and it is someone else sending it. The purple arm band also means multiple things to multiple people, for example there might be people who would read it as a violation of human rights, therefore the purple arm signifies “this person has been victimized, therefore I should treat him more carefully”.
- The purple arm band is a good example of a trace that can be decoded in multiple ways
- Need to probe for more examples in which the person uses the same trace to communicate different messages to different people
- The multiplicity of meaning in traces is unique to our social settings and sophistication as humans
- Moving forward with data collection, focus on asking questions to refine a definition of a trace in healthcare (follow the process similar to Jennifer's definition of allowing to fail – check it out!). In her case, the definition emerged out of looking at all the examples she collected and then she used the examples to illustrate the dimensions of the definition in the paper.

- Craft a potential definition based on the examples I have and then ask myself the question of what would the components of the definition of a trace be? Potential dimensions of the definition: promoting indirect communication, prompting action, intentionality, multiplicity of meanings which could be used on purpose (people can see it in multiple ways), failed traces
- Another consideration for future interviews: the fact that really good clinicians read traces from patients better than other clinicians. Example from Mark on when he knows that the patient is ready to go home because when he comes to see them on day 9, they have their hair done and the lipstick on. For him it prompts the action of talking about discharge. Are there traces that they are trained to read as part of their diagnosis and management process? Ask Mark for more examples such as this one!
- Also explore further the idea of *successful* and *failed* traces (use the Bromiley's case an example), as well as the idea of *resisted* traces, which begs the question of whether there is a broader array of traces.
- Thinking about a potential taxonomy then we can ask what kind of trace is it?: Is it physical? Is it technological? And then what's the effect of the trace?: is it the desired effect? A different effect? No effect (when it is ignored)?
- An interesting way of doing the taxonomical description could be by mapping out the social life of a trace from creation to expiration: how is it placed? What's its nature? What actions or response does it provoke? What are all the variations that a trace can take in its life (e.g., the purple band took a life on its own from being a trace to becoming a movement)? What's the expiration of a trace in our context?

Insights to consider for discussion:

- Double-barreled traces highlights the importance of context because on a busy day you might use traces more than during a not busy day. And also that traces indicate more than action, they are often for-action but most times, they indicate more than that.
- Revision for the hook: if we understand more the role of indirect communication, then rather than just advocating for direct, can we advocate for productive combinations. Therefore if we can find a way to advocate for certain forms of indirect communication. For examples in situation where there is no time for a conversation or when people work asynchronous and they cannot be together?
- There is strong overlap with sociomateriality but it's not a reason to worry but need to acknowledge and need to articulate what's unique to the swarming perspective: **I am interested in traces for the collective communication purpose.** Sociomateriality is interested in objects for other reasons, not necessarily for teamwork. My specific angle is the teamwork and swarm aspect. **What's unique might be the intentionality** part (i.e., the leaving of the coat). I am not interested just in the coat as a sociomaterial artefact, I am interested in the intentionality behind the artefact. **It is about the potential of traces for improving interaction.** My focus is still on the social with humans using

objects intentionally for interaction purposes, not that objects have agency. In sociomateriality, objects and humans are equally important (MacLeod 2019).

- Although we are good at understanding the meaning of a trace in a context, we don't necessarily recognize it as a *message*
- Co-existence of different meanings in the same trace in the same situation depending on who is "reading" the trace
- Can stigmergy help us think differently about the challenge of negotiating the definition of the problem? by directing attention to the traces of work that signal other people's definitions of the problem and building/acting on it to create our own definition of the problem? Even though each person acts individually, I am thinking that the "traces" of their definition of the problem might be part of what makes the team to define the problem collectively. Currently, because of our strong reliance on leaders and scopes of practice, I am not sure that team members are attuned/aware to perceive other people's traces or whether they only perceive the "trace" left by others like them, not the traces left by people in different roles? And even further, I am not sure to what extent they are empowered to enact their self-determination in response to perceiving the "traces" of others?
- Direct vs. indirect communication in humans is not black and white, same as explicit vs. implicit – will have to discuss this issue!: Given the complexity of human culture and engagement, traces can have different meanings to different people in different situations, indicating that for the most part, we use traces as an implicit form of communication (ants use traces as explicit communication!)
- Traces blend into our day-to-day without our notice, but once one begins looking, they seem to crop up all around and in every situation. E.g., a practice common in Italian espresso bars where waiters place empty saucers on the counter next to the espresso machine which communicates to the barista that these are to be filled with cups of coffee.
- A few participants have brought up the idea of how the word "swarming" or "swarm intelligence" has been taken up in medicine literature as "all come together quickly to solve a problem (e.g., cardiac arrest)" and that the way I am describing it (I prefer "swarm intelligence") seems to entail a more complex set of concepts behind. This makes me realize that one of the purposes of this paper is also to move the notion of "swarm intelligence" from its colloquial uptake to positioning it as a scientific term. Might need to do a quick search of literature to see the trend of colloquialism of the term. *Swarm intelligence systems are typically made up of a population of simple agents interacting locally with one another and with their environment. The agents follow very simple rules, and although there is no centralized control structure dictating how individual agents should behave, local interactions between such agents lead to the emergence of intelligent collective behaviour.*
- High level explanation of SI diagram: The principles of communication (**solidarity and stigmergy**) are possible because of the **awareness** and **self-determination** of individual members. The most important feature of swarm intelligence is that the behaviours of individual swarm members do not determine how the swarm functions, rather their

ability to perform distributed work (i.e., similar tasks are accomplished by different members of the system). In human societies, specialization (i.e., role separation) has shaped our history in important ways however with swarm intelligence, distributed work has proved extremely effective. Because there is no division of labor, individuals are interchangeable and an individual currently performing one task can replace another individual performing another task. In this way, the collective exhibits **self-healing** behaviour by becoming very robust to the loss of individual swarm members because no member is irreplaceable. Swarm intelligence principles allow for problems to be solved in a bottom-up way – the collective is a **self-organizing system** – with no central controller or leader.