A Taxonomy of Behavior for a Medical Coordinator by Utlizing Leadership Styles

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Abstract—This paper presents a taxonomy of non-technical skills, communicative intentions, and behavior for an individual acting as a medical coordinator. In medical emergency situations, a leader among the group is imperative to both patient health and team emotional and mental health. Situational Leadership is used to make clear and easy-to-follow guidelines for behavior depending on circumstantial factors. Low-level leadership behaviors belonging to two different styles, *directive* and *supporting*, are identified from literature and are included in the proposed taxonomy. The high-level information in the taxonomy consists of the necessary non-technical skills belonging to a medical coordinator: *situation awareness*, *decision making*, *task management*, and *teamwork*. Finally, communicative intentions, dimensions, and functions are included. Thus this work brings high-level and low-level information - medical non-technical skills, communication capabilities, and leadership behavior - into a single versatile taxonomy of behavior.

Keywords—Medical, leadership styles, taxonomy, human behavior.

I. INTRODUCTION

IN an emergency room, a medical coordinator's job is to facilitate all coordination and procedural tasks [1]. A coordinator is defined as a person whose role involves either managing the team, managing the technical tasks, or both [2].

During remote expeditions, emergencies may arise requiring medical procedures to be completed by those who may not be medical experts. Situations such as these call for (1) a medical procedure coordinator equipped with medical knowledge, and (2) a leader among the group, which is imperative to patient health and collective group emotional and mental health [3]–[5].

This work explores how a person who may be medically inexperienced can assume the role of medical coordinator to successfully lead a team through medical tasks. Ultimately, the behaviour identified in human medical coordinators will be applied to a virtual agent who will act as the coordinator and liaison between the caregivers in the emergency situation and a remote team of medical experts. In this paper, a taxonomy of medical coordinator non-technical skills, communicative intentions, and specific individual behaviors are proposed to enable a person to act as a medical coordinator in an emergency situation.

Three principle factors drive this research:

First, current taxonomies for healthcare professionals are specific to surgeons [6], [7] and anesthesiologists [8]. These taxonomies are detailed in some regards but are missing

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clear and concise rules of specific behaviour. Additionally, the details from taxonomies such as these do not include information on how a person is to gain the trust from the caregivers or how he or she can maintain a healthy team relationship within the group during a stressful situation. In other words, no information is currently provided on how a coordinator is to lead the team.

Second, the ability to lead a group of non-experts is imperative and relevant in an age of continued exploration. As mentioned, for emergencies on remote sites, like ships and space, often the caregivers are not medical professionals [3]–[5]. Thus a coordinator needs to take into account that the team may be made up of novices *and* experts. The person who assumes the role of medical coordinator will be able to successfully lead any team with the taxonomy proposed here. The taxonomies listed in the previous paragraph do not take into account any variation in caregiver knowledge or experience.

Third, the current taxonomies involve a coordinator who is involved in the procedure itself. Surgeons and anesthesiologists, for example, participate in the medical procedure themselves. In the event of an emergency situation at a remote site, however, the coordinator needs to be free from tasks in order to (1) be available for communication with the medical expert team and (2) make sense of the data and information about the patient that the caregivers have. Additionally, a virtual agent acting as a medical coordinator cannot take part in the procedure itself. No current taxonomy accounts for a coordinator needing to communicate with a separate medical team or needing to be the sole person to analyse patient data.

The necessity of a coordinator is explored in several prior papers [9], [10]. A coordinator was found to be beneficial in terms of medical care professionals' attitudes and the end result of the procedure, with a successful coordinator being one who interacts in a respectful and helpful way with the other care professionals and also directs the care team towards the best outcome for the patient. Additionally, previous studies have shown that the best procedure results are attained by a leader embodying the most appropriate leadership style [11], [12]. Thus this work heavily involves Situational Leadership [13] in order to give the coordinator the appropriate behavior that caregivers will respond positively to and will allow them to work together more effectively [14]. The taxonomy proposed here not only allows a person to lead a group of people, but it also gives that person the high-level (such as communicative intentions) and low-level (such as gaze behavior) information necessary to accomplish

that. A subset of the taxonomy demonstrating the relationship between high- and low-level information is available in Table I. Situational Leadership and how it is utlized in this work is further discussed in Sections II and III.

With this taxonomy, the coordinator does not necessarily need to do any reasoning on his or her own. A team of medical experts will stand by in the remote medical center to observe the medical procedure. The role of the coordinator is instead to maintain relationships between the other caregivers and lead them through the already-formulized procedure successfully. The procedure steps and other nominal information is provided to the coordinator beforehand. When the coordinator communicates a task, the task in question comes directly from the nominal procedure, the existing knowledge base from the person, or from decisions made by the medical experts in the remote medical center.

In order for a coordinator to gain the trust of the caregiving team, he or she must display competence [8], [15], confidence [9], [16], and delegate tasks efficiently and appropriately [1], [6], [7], [9], [15], [16]. In an emergency situation, non-technical skills often affect the outcome more than technical skills [9], [15]. In this research, emphasis is placed on non-technical skills as technical skills are embedded in a knowledge-base created by the medical experts that the coordinator will have access to. Additionally, this research does not function as a technical manual; it is assumed that the coordinator and other caregivers will have the most vital technical skills beforehand; the caregivers are given step-by-step technical instructions by the procedure itself, relayed through the medical coordinator.

A taxonomy is proposed, split into two sections for ease of comprehension, to enable the coordinator to embody certain relevant non-technical skills and to effectively communicate with the rest of the caregivers. The taxonomy is designed to be applicable to a variety of medical procedures. Non-technical skills, individual behaviors belonging to two different leadership styles, and the steps in between the two are described.

This research addresses the following questions:

- What are the fundamental non-technical skills that a medical coordinator can enact during a medical emergency?
- What communicative intentions are applicable for such a coordinator?
- Through behavior, how can a coordinator gain the trust of the rest of the caregivers and lead them through a procedure?

In this paper, situational leadership is outlined and defined (Section II), specific low-level leadership behaviors are listed (Section III), non-technical skills and communicative intentions of medical coordinators are explained (Section IV), the proposed taxonomy is described (Section V), conclusions are drawn and reflected upon (Section VI), and the anticipated taxonomy in use in the medical environment is detailed (Section VII) with immediate next steps (Section VIII).

This work exists within the VR-Mars project[1].

[1]https://www.enib.fr/vrmars/

II. SITUATIONAL LEADERSHIP

As mentioned in the previous section, this work focuses on ultizing leadership styles to enable a person to lead caregivers who may be inexperienced during a medical procedure. The concept of leadership styles was first introduced by Hersey et al. in 1988 [13] and expanded upon in 1993 [17]. Born out of a series of studies that appeared to have conflicting results in terms of what kind of leadership yields loyal and competent followers, Situational Leadership aimed to address those discrepancies by proposing a behavior model. In this model, behaviors are classified according to the capabilities and attitudes of the *followers* in the situation. Thus Situational Leadership is one in which the goal, the present circumstances, and the followers' information and emotional states inform the behavior of the leader. The model takes into account that leaders and followers aren't always in strict hierarchical roles; sometimes, the leader is a peer rather than a boss. The followers' levels of competence, commitment, and confidence affect the leader's socio-emotional (referred to here as relationship) and directive levels of behavior.

The four follower styles are defined as: [17] nolistsep noitemsep

1) Incompetent and noncommittal OR incompetent and unconfident;
2) Incompetent but committed OR incompetent but confident;
3) Competent but noncommittal OR competent but unconfident;
4) Competent and committed OR competent and confident.

Thus the four leadership styles are defined as: [17] nolistsep noitemsep

1) Directing: high amounts of directive behavior and low amounts of relationship behavior;
2) Coaching: high amounts of both directive and relationship behavior;
3) Supporting: high amounts of relationship behavior and low amounts of directive behavior;
4) Guiding: low amounts of both directive behavior and relationship behavior.

There is no leadership style that is better than the others because each one is appropriate for different followers and situations. Ultimately, the leader determines what leadership style to use. Paying close attention to the followers and what areas of their tasks are most important will lead to the most appropriate style of leadership [13], [17].

Situational Leadership was tested in an educational setting in which teachers were trained and told to implement the styles to their classes and on an individual basis. Students were found to have more enthusiasm for the material and statistically significantly performed better. In a work setting, managers who use Situational Leadership rate their subordinates as higher performing [12], [13], [17].

The successful use of situational leadership relies on correctly identifying the follower style. Input from followers that can indicate a particular style include: [18]

- Prior experience and knowledge;
- Dialogue;

- Non-verbal behavior such as body movement, gaze, etc.;
- Non-anatomical behavior such as the number of questions asked, the amount of hesitation after receiving tasks, etc.

These modalities will be the subject of future work.

III. LEADERSHIP BEHAVIORS

This section examines non-verbal behaviors that leaders employ. As mentioned in Section II *Situational Leadership*, this research involves using leadership styles to select agent non-verbal behavior. Non-verbal behavior exists to (a) provide information, (b) regulate the interaction, (c) express intimacy, (d) act as social control, (e) present identities and images, (f) affect management, and (g) facilitate service and task goals [11]. Individual behaviors can then be thought of as belonging to one of these seven dimensions.

While the literature contains many examples of behaviors belonging to various leadership styles, only those that are confirmed by multiple pieces of research are included here.

Behaviors that are indicative of all good leaders have been grouped under *All Leadership Styles* (Section III *A*) while those that are employed by poor leaders are discussed under *Behaviors to Avoid* (Section III *B*). Leadership styles 1 and 2 have been grouped together as well as styles 3 and 4 for this primary investigation. Therefore other non-verbal behaviors are listed under *Leadership Styles 1 and 2: Directing and Coaching* (Section III *C*) and *Leadership Styles 3 and 4: Supporting and Guiding* (Section III *D*). Appendix A displays all of the behaviors covered in this section.

A. All Leadership Styles

Throughout the literature, several behaviors emerged that appear to always generate a positive user response. These behaviors are determined to be ones that all leaders, regardless of style, should employ.

Perception of leaders is based largely on composure, competence, as well as warmth and general likeableness [19]. Therefore all of these are important to some degree and determine whether a leader is a good one or not. In one study, gender was not found to be correlated with power level [20], and therefore gender will not be discussed further in this section.

Note that cooperation is mentioned often in this subsection. Cooperation and dominance often act as opposites when it comes to social interaction [12], [21], [22], where cooperative qualities rank higher in users' perceptions of the individual and dominant qualities rank lower. Cooperation refers to a person's ability to work well with others, which is hugely important in the context of a medical scenario [12], [22], [23]. Users have been found to be more trusting of cooperative leaders rather than dominant ones [21], [24]–[26] (covered further in the following section).

Good leaders are seen as more forthcoming, open, and physically expressive. In terms of body expression, they tend to have more erect posture and more forward lean [20]. Expressivity itself is seen as being of higher power [20], while constrictive gestures are regarded as being powerless [27]. Regardless of their positivity or negativity, bodily expression itself is seen as being more cooperative than uniform expression [21], [25].

Eye contact is generally perceived as a sign of good leadership, maintaining focus on the individuals or object of most importance and also sustaining the relationship aspect of the interaction [28]. Gaze also implies power; more eye contact towards the followers is perceived as more powerful [20]. In a medical context, the more a person looks at a follower or at the patient, the more he or she is perceived as being proactive [22]. In one study, patients were likely to give higher ratings when medical students faced them directly, nodded when listening, and looked at them equally when talking and listening [23].

Smiles, defined technically as an upward curvature of the mouth and lips, are seen as expressions of joy or friendliness [29], [30].

Head tilts in general are perceived as cooperative [21]. Aside from nodding while listening, which often indicates affirmation, thinking, or emphasis, a tilt of the head may indicate thinking or hesitation. Lateral head movements can refer to specific objects in the space, directing users to look towards something [31].

The use of hands, more than heads and gaze, have been found to increase both humans' and virtual agents' verbal eloquence [32]. In fact, users have been able to interpret more from gestures than speech, tone, facial expressions, and gaze [19]. Palms-upward gestures may be a signal of offering: the person may be showing or giving something (the "something" may be intangible), or they may be requesting something [33]. Ideational gestures, ones that directly refer to objects or ideas, such as the drawing of a circle with the fingers to indicate a circular concept, are effective at communicating ideas. They often result in more understanding and thus a perception of higher competence of the leader [19]. Steepling of hands translates as confidence and competence [34], leading to a better perception of the leader.

In one study, people were found to be more likely to answer "yes" to a question when the question ended with a rising voice. People were also more interested in the question and more invested in answering if it ended with a rising voice. Regardless of the reasons for why this might be, there is substantial evidence that voice intonation affects user responses [35]. When a speaker has matched the tone and volume of the person he or she is speaking to, the speaker is perceived as a better listener and kinder. A leader's voice has a large impact on followers' emotional state, often making them feel more anxious or less anxious depending on how well the intonation, speed, and volume of speech matches those of the user [23].

B. Behaviors to Avoid

Similarly to the *All Leadership Styles* section, there are behaviors that all leaders regardless of style should avoid. Dominance, referring to a person's ability to control a situation and other people, can lead to animosity or a feeling of being threatened on the team [36]. Additionally, submissive behaviors should be avoided as a leader must be recognised as the authority figure at all times [22].

Expansive gestures in which arms and hands are open and away from the torso are perceived as dominant and should be avoided [20], [36], [37]. Other dominant behaviors to avoid include the akimbo posture[2] [21], crossing of arms [21], hands clasped together [29]. The turning of the head towards a fellow follower is seen as being less cooperative [21]. Both upward head-tilts and downward head-tilts can indicate dominant assertion and condescension [38], [39]. Gazing less at followers, particularly when they are speaking, is seen as dominant behavior [20]. Finally, the raising of eyebrows can be interpreted as negativity [40].

Only one submissive behavior to be avoided has been identified: self-touch has been found to indicate low power [20], [41]. Self-touching gestures may have positive effects on the user, increasing the level of warmth and friendliness perceived [21], [40]. However, self-touch can be an indication of insecurity, so it is possible a self-touch behavior may make the leader more relatable [40], but gestures such as those are not indicative of leader behavior.

Finally, tense lips, lips that are pursed together and unsmiling, can be indications of thinking or of disagreement. They can be perceived negatively and so are best to avoid [42].

C. Leadership Styles 1 and 2: Directing and Coaching

As discussed in the *Situational Leadership* section, leadership styles 1 and 2 work with followers who are of lower competence and confidence. Thus leaders of styles 1 and 2 must be more directive to combat incompetence and more coaching to combat insecurity. The behaviors listed here belong to the directive and coaching categories.

Maintaining eye contact with each follower is hugely important to ensure followers are listening and able to follow along [20].

The very presence of hand gestures increases the perception of competence [37]. In the previous subsection, ideational gestures were mentioned as a way of conveying specific ideas like where the follower should act on the patient (e.g., for cardiopulmonary resuscitation, abdominal palpitations, etc.). Directive leaders will clearly articulate instructions to followers who may not otherwise know what to do. Additionally, pointing gestures are seen as being especially proactive, since they are a clear ideational gesture indicating what the user is meant to do [22].

Instances in which the leader disagrees with the followers are likely to occur for leadership styles 1 and 2. In cases such as these, palms-downward gestures can indicate a wish to stop the current situation: they may want to interrupt the situation because the user doesn't understand, they disagree with the way things are going, or things are moving too fast [33], [43]. A shake of the head can indicate disagreement as well [31].

D. Leadership Styles 3 and 4: Supporting and Guiding

Leaders of styles 3 and 4 work with followers who are of higher competence and confidence, and so they need different behaviors to support and guide rather than direct and coach.

[2]standing with straight posture and both hands on the hips

In cases like these, the leader takes less of a role during the procedure and only steps in when necessary.

Since these leaders are operating from less of a position of power, even more cooperative behavior is necessary. This means that behaviors such as forward leans [20], [44], head tilts [21], voice (intonation, speed, and volume) matching [23], and overall more expressive behavior [21], [25] will be required.

When hands are together and palms are turned upward, the leader may be indicating that they are withdrawing from the current task or do not want to intervene in the current situation [43].

Finally, wide eyes can indicate praise or support of the followers and/or tasks at hand [42].

IV. Previous Taxonomies on Non-technical Skills and Communicative Intentions

Recognising the appropriate follower style from users and choosing the related leadership style is tricky for many leaders. The medical environment adds some complication, however, as leadership behaviors must be performed in the context of precise medical tasks and often restrictions of time. This complication is addressed in the form of taxonomies: road maps that guide leaders and professionals toward the most optimal way of handling various situations, both in terms of relationships with followers and in terms of medical tasks.

Section IV describes the non-technical skills needed by a coordinator during a medical procedure (Section IV *A*) and examines previous taxonomies solely in relation to communication intentions (Section IV *B*). Section V then outlines the proposed taxonomy structure for a medical coordinator using leadership styles to lead a team of caregivers.

A. Non-Technical Skills and Communicative Intentions for Medical Coordinators

There are several prominent taxonomies of non-technical skills for medical professionals. Three of these have provided a foundation for the taxonomy developed in this paper.

Designed in 2006, the Non-Technical Skills for Surgeons system aims to address key skills that surgeons need during an operation that enables them to lead a team of medical caregivers [45]. In many medical procedures, a coordinator is not present and instead the surgeon acts as the leader [6], [7], [9].

NOTSS has been tried and tested in various medical environments [45]. Five non-technical skills are identified: *Situation Awareness*, *Decision Making*, *Task Management*, *Leadership*, and *Communication and Teamwork*. After analysis from a series of videos of procedures, leadership was found to be the primary determinant of procedure success. Some of the sub-skills under leadership deemed important include elements like competence, interest in medicine, calmness, and alertness [7], [9]. Some of these elements are relevant to this research, but some are arbitrary; "interest in medicine" for example, is irrelevant to the taxonomy developed in the paper as the medical coordinator only needs to be able to lead an

emergency situation. In this way, the NOTSS taxonomy was evaluated and edited for an application to an inexperienced medical coordinator.

Unlike NOTSS, the Anesthesiologists Non-Technical Skills taxonomy was made primarily for anesthesiologists, not surgeons or leaders of the medical procedure [8]. Thus the "leadership" category is removed, leaving the following four categories: *Task Management*, *Team Working*, *Situation Awareness*, and *Decision Making*. These categories are broken down into various elements and examples similarly to NOTSS. However, there has not been as much reliability testing done with it since its creation in 2010. Regardless, the non-technical skills and communicative intentions listed are valuable for this research and have informed this taxonomy.

In 2013, the Surgeons' Leadership Inventory (SLI) taxonomy was developed from a series of videos of surgical operations, similarly to NOTSS [6]. The ability for the leader to make decisions was labelled as a vital skill - this serves as a reminder that the baseline is making decisions at all, not jumping to making positive or negative decisions. In other words, indecisiveness is the worst attribute for a leader to have during a medical procedure. In this taxonomy, *Communication and Teamwork* operate under separate categories, with separate elements belonging under each. Of importance to note is that the study mentions that surgeons' leadership could very well depend on the *type* of operation as different tasks are required under different procedures. Our work aims to eliminate this kind of uncertainty in leadership by writing formulized procedures (more on this is in Section VIII *Future Work*).

A number of papers have been published in recent years and earlier on non-technical skills in a medical context that confirms the ideology behind NOTSS, ANTS, and SLI. In one study, a coordinator's primary role was found to be handling communication and coordination [10]. In a second study, *Task Management* was found to positively and/or negatively affect the outcome of a medical scenario. Each task has prerequisites, corequisites, and postrequisites in terms of tasks or communication, and the coordination of those tasks can determine procedure success [15].

B. Communicative Intentions, Dimensions, and Functions Outside a Medical Context

The focus of this work is on human behavior as it applies to virtual agents, and so further research on human intentions was explored in the virtual agent domain. In many regards, virtual agents and inexperienced human coordinators are similar: they both start with a base knowledge of zero and must be given specific information in order to complete tasks successfully. Thus several works involving virtual agent behaviour have informed the taxonomy presented here in order to make a complete and comprehensive guide for a medical coordinator during an emergency situation.

A communicative intention is, simply put, what the speaker wants to achieve with a piece of communication. Questions, invitations, confirmations, and promises are all examples of communicative intentions. Communicative form, or linguistic form, is the format that a piece of communication takes. A dimension then represents the type of communication that is required, and a function represents the form that the communication takes. All of these together change the addressee's information state by adding information or correcting information. The communication can thus be defined by its form: for example, a question uttered by the speaker has the intention of receiving an answer and the form of a question. However, speakers may not always be aware of their intentions when they speak and thus their forms may not be directly related to the dimensions. Intentions, dimensions, and functions are discussed more in-depth in [46].

Informing the proposed taxonomy is the Dynamic Interpretation Theory++ (DIT++) taxonomy, a work which aims to identify and define dimensions, both in terms of dialogue and in terms of non-verbal behavior [46]. This work defines certain rules for future taxonomies: emphasizing the importance of theoretical foundation and suggesting different forms of organisation such as clustering dimensions by general-purpose or function-specific. The DIT++ specifies aspects of communication that this research would classify as belonging to situational leadership: aspects such as direct and indirect communications ("What time is it?" vs "Do you know what time it is?"), certain and uncertain answers from users, and how verbal and non-verbal behavior often co-occur. The most important non-verbal signals are found to be present in feedback, turn management, and own (or self) communication management.

In 2019, a dialogue-act taxonomy for a virtual coach for improving the lives of the elderly was created based on the DIT++. The work places a huge emphasis on empathy: how the agent can establish a relationship with the human(s) it works with. The taxonomy itself shows the flow from communicative intention to dimension. Importantly, multi-modal communication is taken into account, meaning both verbal and non-verbal communication. The taxonomy introduces a method of tags that act like functions and user reactions from previous papers ([46], [47]): topics, which help the agent keep track of conversation changes; intents, like "question", "inform", etc.; polarity, meaning positive, negative, or neutral; and entities, such as dates, quantities, etc. These four tags take on a hierarchical structure, with "topics" existing at the top and "entities" at the bottom, which allows semantic information to be gathered at each step of the process. This taxonomy is hugely important to the work in this paper as the concept of tags or functions applies well to interpret follower reactions and behavior (more on this is covered in the next section).

Taxonomies for communicative intentions and skills outside of a medical context have been developed and used for various situations long before virtual agents were a topic of interest. For example, in 1976, behaviors of young children were organised into a taxonomy, which laid a baseline of defining desires, needs, and interaction [48]. In 1992, a baseline for general overriding dimensions was established: speech management, interaction, and focused messaging [47]. In 2001, a taxonomy was defined for educational purposes, focusing on objectives and cognitive processes [49]. These

dimensions have informed the taxonomy proposed in this paper, explained in Section V.

V. PROPOSED TAXONOMY OF NON-TECHNICAL SKILLS AND COMMUNICATIVE INTENTIONS

This paper proposes a taxonomy that addresses the information in the two previous sections: the non-technical skills of the medical coordinator and the communicative intentions needed to communicate with the rest of the caregivers. Several pieces of research address non-technical skills of coordinators [7], [8], [15]. The works mentioned previously [46], [47] regarding virtual agent intentions and dimensions do not account for a medical environment. Thus this work aims to define a taxonomy that brings together necessary skills in a medical context and also the necessary skills for interaction with a human caregiving team.

The taxonomy begins with four non-technical skills and their respective elements, a subset of which is shown in Table I (the full taxonomy is shown in Appendices B and C). SLI, NOTSS, and ANTS [6]–[8] provided the groundwork for the skills and elements listed here. However, several were removed as they did not make sense when a person who assumes the role of coordinator is not participating in the procedure itself (e.g., "takes over task leadership as required" [8]). The fifth category in the NOTSS system, leadership, is removed because leadership plays a large role in the coordinator behavior and thus nearly every non-technical skill has aspects of leadership at the low-level interaction stage [45]. Important to note is that the skill *Situation Awareness* does not involve interaction with caregivers and therefore does not call for a leadership style.

Each non-technical skill is divided into elements, referring to the various sub-tasks that are related to the overarching skills. Table I displays three of the elements included under the non-technical skill *Teamwork*. Unlike several of the previous taxonomies examined in Section IV, *Communication* is not considered a separate non-technical skill; instead it applies to every skill and intention that involves interaction with followers. These elements are further divided into communicative intentions. By design, communicative intentions seek to obtain or provide information. They can also show an emotional state or a level of certainty about the current circumstances or about the information the user is imparting. Communicative intentions, as they are defined in this work, do not change with a change in leadership style. Rather, the leadership style dictates *how* the intention is communicated.

As mentioned previously, the non-technical skill *Situation Awareness* and all of its elements and communicative intentions does not call for a leadership style. There are other specific communicative intentions within the taxonomy that also do not call for a leadership style as they do not require interaction with the caregivers, and thus there is no dimension or function specified. For those intentions that do require interaction, one of two dimensions is listed: *communication management* or *interaction*. The taxonomy in [47] provided a foundation for the dimensions. Here, only two are chosen: communication management (labelled *speech management* in [47]) and interaction. A third dimension, *focused or main*

message dimensions, is specified in [47] but was found to be arbitrary in this work as all communication coming from the medical coordinator is focused.

These communicative dimensions are divided into communicative functions, as shown in Table I. Several prior papers use communicative functions [46], [47], [50], [51], and these formed a groundwork for the functions chosen in this taxonomy. *Reporting*, the only function belonging to dimension *communication management*, refers to the relaying of information without the need for user feedback. Announcing patient state, like blood pressure, would belong to this category. Functions *turn-taking*, *sequencing*, and *giving feedback* belong to the *interaction* dimension. *Turn-taking* involves many sub-functions such as *listening*, *releasing turn*, etc., which will be handled within a dialogue manager [46] (this is covered further in Section VIII *Future Work*). *Sequencing* in this context involves relating the tasks and the task order to users [47]. *Giving feedback* involves multiple aspects of communication: listening, interpreting behavior correctly, and communicating feedback in such a way that followers are able to adopt necessary changes without damaging feelings or relationships [47]. The idea is to correct bad behaviors so that the health of the patient and relationships within the team are maintained.

Each function includes potential follower reactions and behavior (which will come in the form of verbal and non-verbal behavior as well as things like hesitation and number of errors [18]; more in Sections VII and VIII). The expected follower style is derived in part from the behaviors listed in the column *Follower behavior*, although it is worth noting that it is impossible to include all possible follower behavior in a taxonomy like this. Instead, high-level reactions indicate the possible general follower behaviors. There are many cases in which further context is needed to determine the follower style, as indicated in Table I. Finally, leadership style is directly derived from follower style as explained in [13].

The goal of the proposed taxonomy is to allow the coordinator a clear path towards either directive or supportive behavior, both verbally and non-verbally. The taxonomy is designed to be comprehensive, with detailed information about what is driving the end behavior from the coordinator. That being said, a human coordinator does not need to focus on each part of the taxonomy: The most important parts are firstly the *Non-technical Skill*, *Element*, and *Communicative Intention* columns so the coordinator can focus on the most relevant intentions for the current task; secondly and the *Follower Reaction*, *Follower Behaviour*, and *Expected Leadership Style* columns as well as the following non-verbal behaviors associated with that style are important so the coordinator knows what to look for and how to relate his or her observations.

The full taxonomy is displayed in Appendices B and C.

VI. CONCLUSIONS

The proposed taxonomy has been developed by a team of researchers specialising in human behaviour, virtual agents, and medicine to create a road map for a medical

TABLE I
A Subset of the Elements, Communicative Intentions, Communicative Dimensions, Communicative Functions, Follower Behavior, Follower Reactions, Expected Follower Styles, and Expected Leadership Styles under the non-technical skill *Teamwork*

← High-Level   Low-level →

Non-technical Skill	Element	Communica-tive Intention	Communicative Dimension	Communi-cative Function	Follower Reactions	Follower behavior	Expected Follower Style	Expected Leadership Style
Teamwork	Exchanging information	gives updates and reports on new events	communication management	reporting	negation	disagrees	expert	supportive
					affirmation	understands	novice or expert	directive or supportive
		confirms shared understanding	interaction	turn-taking	negation	disagrees	expert	supportive
					affirmation	agrees	novice or expert	directive or supportive
	Coordinat-ing team activities	confirms follower roles and responsibilities	interaction	sequencing	negation	rejects task	novice	directive
					asks question	doesn't understand	novice	directive
	Using authority	asserts when followers make errors	interaction	giving feedback	needs clarification	doesn't understand	novice	directive

coordinator to follow when leading a team of caregivers. Several taxonomies of non-verbal behavior, including the ANTS [8], the NOTSS [7], and the SLI [6], as well as taxonomies of agent behavior, including the DIT++ [46], have informed the proposed taxonomy in this paper. As discussed in Section 5 *Proposed Taxonomy of Non-technical Skills and Communicative Intentions*, pieces of these taxonomies were removed and adapted to suit the nature of this work.

A taxonomy encompassing both non-technical leadership skills and interaction skills does not exist currently. With some tweaking, this work is applicable not only to a medical environment, but to a wide-range of other scenarios in which a non-expert must lead a group of others. The work in this project at large lends itself well to other instances in which an agent leads a group of people by proxy of a distanced expert, such as on-board technical assistance on boats and planes.

VII. Anticipated Use of the Taxonomy

When communicating with other caregivers in an emergency situation, adapting the communication style to the individual is pertinent for procedure success. No one likes to be talked down to, and caregivers are no exception. Our observation indicates that caregivers who consider themselves experts do not like being spoken to as if they are novices, and such an instance can disrupt the flow of the procedure. Thus as pointed out in [18], correctly identifying the prior knowledge of each follower is vital to the procedure as a whole.

In practice, dealing with both novices and experts requires the coordinator to step back when appropriate in order to allow novices enough time to complete the task and to allow experts to prioritise another task as necessary, to ready the equipment, or to exchange information with the patient and/or other caregivers. For example, examine the task of taking a patient's blood pressure: the coordinator requests the task then allows for a minute to go by. Failure of the follower to take

the patient's blood pressure within this time frame can indicate one of three things:

1) The caregiver does not know how to complete the task or has forgotten to do the task;
2) The device is lost or broken;
3) The patient has interfered with the procedure.

At this point, the coordinator should ask the follower if he or she requires assistance. As discussed in the Introduction, the followers' ability to turn down help from the coordinator is important as it established autonomy of the caregivers in the situation.

From observation, an immediate directive approach from the coordinator is rarely effective when a follower has hesitated or made an error (assuming it is not life-threatening). Instead, the coordinator should first assume a supportive leadership style, "observing" the caregivers and allowing them to organise themselves until the situation requires directive behavior. Immediate directive behavior from a coordinator is seen as intrusive and overbearing.

VIII. Future Work

An important piece of this research is defining what makes a successful procedure with the coordinator. We envision a combination of the physical outcome for the patient as well as the stress of the caregiver team being necessary measurements to define success, with the former being weighted more heavily.

As the purpose of this taxonomy is to allow a person or virtual agent to lead a medical procedure, the procedure itself plays a vital role. The procedure for diagnosing and managing abdominal pain is currently being formulized in an easy-to-follow guide. The procedure itself may influence the leadership style when, for example, a very difficult or detailed task needs to be completed. Because the procedures are formulized (in an easy-to-read flow chart for the human and in code for the virtual agent), there will be no uncertainty as to

whether the coordinator can lead a group of followers through each task. The non-technical skill *Task Management* will play a huge role when integrating with the formulized procedure - the prerequisites, co-requisites, and post-requisites of each task and whether they have been completed successfully will influence leadership style.

Leadership style will also be influenced by the medical team in the remote medical center. It is envisioned that there will be some latency between the medical experts and remote caregiving site. When an order comes in from the experts, the coordinator's leadership style may need to change drastically if the order specifies a redirection within the procedure. The medical coordinator will need to find a way of switching leadership styles in a way that is not jarring for the caregivers. Latency itself is the subject of more research within this project.

Since situational leadership is key to this research, and follower style directly influences leadership style [13], [17], identifying follower style is prudent. Certain modalities are envisioned to identify follower style, such as prior experience and knowledge, dialogue content, non-verbal behavior, and non-anatomical behavior (such as number of errors made in a certain amount of time, the amount of hesitation before and during tasks, etc.) [18]. These modalities will be monitored and assessed during Experiment 3 below.

We will conduct three experiments in order to validate the taxonomy presented here:

1) Experiment 1: Coordinator non-verbal behavior. Videos will be shown to participants, two at a time, side by side, with one depicting a non-verbal behavior that is listed in the table of leadership behaviors in Appendix A and one depicting no non-verbal behavior. Participants will determine when the non-verbal behavior video is more directive, more supportive, or neither as compared to the control video. This experiment will validate the non-verbal leadership behavior.

2) Experiment 2: Coordinator dialogue. Similarly to Experiment 1, videos will be shown to participants, two at a time, side by side. For each non-technical skill, one video will show a coordinator uttering a sentence indicative of one leadership style or the other, and a second video will show a coordinator uttering a neutral sentence. Participants will determine which video contains behaviour that is more directive, more supportive, or neither. This experiment will dialogue and characteristics of dialogue that belong to both leadership styles.

3) Experiment 3: Follower behavior. Participants will be asked to complete the formulized procedure while being videoed. Surveys before and after the experiment will help determine participants' true follower style. Participants will be asked to reflect on which tasks during which they felt they were more novices and during which they felt more experts. Participant dialogue, non-verbal behavior, number of errors made in a certain amount of time, the amount of hesitation before and during tasks, and the number of questions asked while completing tasks will be measured and later analyzed to define novice and expert behavior profiles.

Once these experiments have been completed, an experiment may be conducted to evaluate the effectiveness of a medical coordinator following the taxonomy presented here.

The taxonomy will ultimately be tested with people in an emergency room simulated setting. This experimentation will firstly tell us how well an inexperienced person can assume the role of a coordinator, and secondly how caregivers react to being led by a coordinator. Observations may uncover how leadership style relies on follower style and how follower style can change *how* communicative intention is realized. The scenarios we plan to test include:

- A coordinator leading a group of people without any leadership style and thus without non-verbal behavior;
- A coordinator leading a group of people with the "wrong" leadership style (supportive behavior when the followers' behavior calls for directive leadership, for example);
- A coordinator leading a group of people with the "correct" leadership style (supportive behavior when the followers' behavior calls for supportive leadership, for example).

APPENDIX A

LEADERSHIP BEHAVIORS

TABLE II

THIS TABLE DISPLAYS ALL THE LOW-LEVEL BEHAVIORS THAT SHOULD COME FROM DIFFERENT TYPES OF LEADERS

Expression Point	Directive Non-verbal behaviors	Supportive Non-verbal behaviors	Both Directive and Supportive Non-verbal behaviors	Neither Directive or Supportive Non-verbal behaviors
body		more forward leans	open posture	akimbo posture
			erect posture	
			leaning forward	
eyes	continuous eye contact	wide eyes to support	eye contact	
			gaze towards followers when speaking to them	
			gaze towards objects of importance	
mouth			smile	tense lips
eyebrows				raising eyebrows
head	shake of the head to disagree	more head tilts towards objects (rather than hand gestures)	nodding when listening	tilt upward towards followers
			head tilts toward objects of importance	tilt downward towards followers
hands and arms	ideational gestures	hands together and palms upward to indicate a withdrawal from the task	palms upward	expansive gestures (hands are far from body)
	pointing gestures		ideational gestures	crossing arms
	palms downward to stop or correct a task		steepling of hands	hands clasped together
				self-touch
voice/verbal		more matching tone and volume	questions ending with a rising voice	
			matching tone and volume of followers'	

The first column, *Expression Point*, refers to the part of the body where the behavior occurs. The remaining four columns describe purely directive behaviors, purely supportive behaviors, behaviors that all leaders should perform regardless of style, and behaviors that no leader should perform.

APPENDIX B
PROPOSED TAXONOMY (PART 1)

TABLE III
THIS TABLE DISPLAYS PART 1 OF THE PROPOSED TAXONOMY

Non-technical Skill	Element	Communicative Intention	Communicative Dimension	Communicative Function
Situation awareness	Gathering information	collects data from the patient		
		collects data from the followers		
		liaises with medical team		
		identifies correct path through the formulised medical procedure		
	Recognising and understanding information	uses patient data to make procedural decisions		
		uses follower data to make procedural decisions		
		compares and analyses current state with expected state		
	Projecting anticipating and future state	works with medical team to predict future states		
		uses patient data to predict future states		
Decision making Identifying	considering and options	generates options for decisions and courses of action		
		recognises potential problems		
	Selecting and communicating options	communicates selected decision	communication management	reporting
		answers questions regarding course of action	interaction	turn-taking
	Implementing and reviewing decisions	reasses patient state		
		schedules tasks		
		updates medical team on progress		
Task management	Planning and preparation	communicates plans from medial team	communication management	reporting
		communicates tasks from formulised medical procedure	communication management	reporting
	Flexibility/responding to change	redirects followers' tasks	interaction	sequencing/ giving feedback
		manages followers' emotions when redirecting	interaction	giving feedback
	Prioritising	communicates priority of tasks	interaction	sequencing
		communicates schedule tasks	interaction	sequencing
	Setting and maintaining standards	keeps patient health at the forefront		
		follows formulised procedure		
	Identifying and ultizing resources	identifies tools for followers	interaction	sequencing
Teamwork	Exchanging information	gives updates and reports on new events	communication management	reporting
		confirms shared understanding	interaction	turn-taking
		clarifies team goals	communication management	reporting
		ensures team members are comfortable with tasks	interaction	turn-taking
		debriefs followers after procedure	communication management	reporting
	Co-ordinating team activities	confirms follower roles and responsibilities	interaction	sequencing
		ensures followers are working together	interaction	sequencin
	Supporting others	comforts, reassures, encourages	interactio	turn-taking
		acknowledges concerns of followers	interaction	turn-taking
		thanks followers	interaction	turn-taking
	Using authority	gives clear orders to team members	interaction	sequencing
		states case and provides justification	communication management	reporting
		asserts when followers make errors	interaction	giving feedback
	Assessing capabilities	calls for assistance when it is needed		
		notices when a team member does not perform a task to the expected standard	interaction	giving feedback
		adapts level of monitoring to expertise of other team members		
		provides feedback to followers	interaction	giving feedback

The left-most column contains each required medical coordinator non-technical skill. *Element* describes the sub-tasks for each non-technical skill. *Communicative Intention* is tasks that seek to obtain or provide information from or to followers. *Communicative Dimension* refers to the type of communication required. *Communicative Function* describes the type of leader behavior required.

APPENDIX C

PROPOSED TAXONOMY (PART 2)

TABLE IV

THIS TABLE DISPLAYS PART 2 OF THE PROPOSED TAXONOMY

Communicative Dimension	Communicative Function	Follower Reaction	Follower behavior	Expected Follower Style	Expected Leadership Style
communication management	reporting	negation	disagrees	expert	supportive
		affirmation	understands	novice or expert	directive or supportive
		confirmation	confirms own understanding	novice or expert	directive or supportive
		acceptance	accepts agent's information	novice	directive
interaction	turn-taking	negation	disagrees	expert	supportive
		affirmation	agrees	novice or expert	directive or supportive
		other	has information to contribute; exchange is over	novice or expert	directive or supportive
	sequencing	negation	rejects task	novice	directive
		affirmation	agrees	novice or expert	directive or supportive
		asks question	doesn't understand	novice	directive
		asks question	needs more information	novice or expert	directive or supportive
		begins task	understands	novice or expert	directive or supportive
	giving feedback	negation	rejects feedback	novice or expert	directive or supportive
		affirmation	accepts feedback	novice or expert	directive or supportive
		asks question	doesn't understand	novice	directive
		makes statement	has more information to contribute	expert	supportive

Continued from Part 1 of the Taxonomy in Appendix B. The *Communicative Dimension* column contains the two dimensions included in the taxonomy. The functions belonging to each dimension are listed in the column *Communicative Function*; one dimension belongs to dimension *communication management* and three belong to dimension *interaction*. The column *Follower Reaction* contains the various anticipated reactions that each caregiver may have in response to the coordinator's behavior (behavior derived from the previous five columns). The *Follower behavior* column contains the behavior, or the interpretation of the follower's reaction in terms of behavior. From here, the *Expected Follower Style* is derived, by taking into account what the follower reaction and behavior means in the context of the coordinator's previous behavior and the current task. *Expected Leadership Style* relates directly to the expected follower style. The coordinator then embodies the low-level behaviors included in Appendix A in order to appropriately and successfully lead the caregivers.

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