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A study of Knowledge Exchange in Handover for the Urban Air Mobility

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Abstract—The aim of this paper is to explore the potential challenges associated with contextualizing handover instructions between different stakeholders in the context of a remotely piloted aircraft. The difficulty of synthesizing pilots' exchanges has already been highlighted. In this study, the operational framework focuses on both the construction of representations and narrative discourse to synthesize the situation. To conduct this study, subjects participated in an experiment in which they were asked to place themselves in a handover situation as an incoming and as an outgoing party. This study has made it possible to identify different strategies for constructing the representation of the situation and for transmitting instructions to contextualize an operation. Using an information gathering analysis method, it is possible to assess not only the relevant elements of the context, but also the narrative progression of these elements in the discourse. This is part of the development of an automated assistant that mediates the sequence and, more generally, the contextualization between two human operators or between a human operator and an artificial agent. Those primary results are the first step towards appropriate standardized protocols and checklists, the implementation of technological solutions such as automation and digital communication systems to improve situational awareness and communication skills. The aim is to identify and apply generic strategies that can be used as a framework for the automated development of effective handover protocols in future UAMs, piloted or remotely-piloted aircraft and other flight operations, contributing to safer and more efficient flight operations.

Index Terms—handover information requirements, content analysis, urban air mobility

I. INTRODUCTION

Rapid advances in aviation technology have led to the emergence of future air operations such as Urban Air Mobility (UAM). While UAM offers opportunities for faster and more efficient transport, it also presents unique challenges that require careful consideration. One of these challenges is the need to improve handover protocols that ensure smooth transitions between different phases of flight and between different stakeholders, such as pilots, air traffic controllers and ground personnel.

A. CROP approach

Taking into account all these prerequisites for an artificial agent system, the aim is to develop an agent system capable of generating a Common Relevant Operational Picture (CROP)

[1]. This common representation space must be comprehensible to all the agents who have to work together (inside and outside the cockpit). Moreover, to be effective and optimal, CROP must integrate only the knowledge relevant to the context of agents, according to their objectives, intentions, constraints and resources, and their respective roles. Fundamentally, this future cognitive assistant system will be able to guarantee effective and relevant knowledge transfer in all types of circumstances and for any operational framework. As The Holy Grail of human factors is to improve the decision making process by having the most appropriate situational awareness. In other words, perceiving, understanding and projecting possible outcomes to achieve the operator's goal. The Holy Grail in the human-factors domain is to enhance the decision-making process by having the most appropriate situation awareness. In other words, perceiving, understanding and projecting possible outcomes to achieve operators' goal [2]. Luokkala reports that situation awareness is created and maintained through time in a narrative form. Operators are gathering new elements and updating old ones in a way to have the most representative form of their current situation [3]–[5]. This process is called situational narratives [4]. Past experiment has shown the importance of the variability of information that each pilot considers salient for the management of its flight mission during Single Pilot Operation settings [1]. In our experiment, pilots showed how difficult is to have a homogeneous transmission of instructions, despite the standardized training given to pilots by airlines. The aim of this new experiment is to understand, with people who are novices and unfamiliar with the aeronautical field, the discourse of non-standardized so-called natural transmission of instructions during the handover.

B. Handovers

Handover is being studied as part of the SESAR research and innovation project [6]. Handover is the most critical phase of the remote pilot state. Handover is defined as the entire process beginning with the 'notification' of either party, and 'takeover' as the point at which control is relinquished [7], [8]. During a changeover, an incoming operator takes over the activity while the outgoing operator monitors.

Specific factors in charge of the handover have been selected from a state of the art composed of different field activities such as health, military, sports, airspace, crisis management and obviously aeronautics. For this experiment, we have selected one particular effect on the handover, the availability to prepare the handover. This effect highlights the capability of the operators to have the time to prepare by notifying them when the handover will be required. The goal of this experiment is to evaluate the ability of having a time to prepare the takeover during the handover phase.

C. Hypotheses

The research question is stated as follows:

- In a complex environment how the operators for future air operation will synthesize their current situation in order for another operator to take over during the handover?

What are the relevant elements from the current situation that should be described during the handover?

What is the situational narrative that needs to be followed during the handover?

To answer those problematic, it has been hypothesized that:

- Preparation of the handover help the subjects to focus their speech
- The information required for a succession can be defined using a symbolic method (syntax and semantic rules)
- The information required for a succession can be defined using a neural method (based on a language model)

II. METHOD

The study aims to compare the influence of availability to prepare the handover. Task designed to evaluate is supported by a simulation tool developed specially for the experiment. Variety of measure in the subject's behavior such as speech has been gathered to evaluate our hypotheses.

A. Simulation with OpenMATB

For the purpose of this experiment, we have developed a custom version of the software OpenMATB. This software aims to provide an Open-source version of the well-known Multi-Attribute Task Battery (MATB) developed by the research team from NASA [9]. This system is composed of a set of interactive tasks that simulate a simplified version of the workstation of an aircraft operator. The MATB requires participants to engage in four tasks presented simultaneously on a computer screen. The Fig. 1 displays the main tasks. They consist of (1) a monitoring task (upper-left), (2) a tracking task (upper-center), (3) an auditory communication task (bottom-left), and (4) a resource management task (bottom-center). The display screen also encompasses (5) a scheduling view (upper-right) for displaying a chart of incoming task events.

Our custom version eases the implementation to integrate speech recording during the scenarios and add modification to the user interface in order for subjects' operators to project themselves better in the scenario. To enhance the immersion in the role of an aircraft operator, a dynamic flight plan course of the aircraft, during the training and the main tasks has been

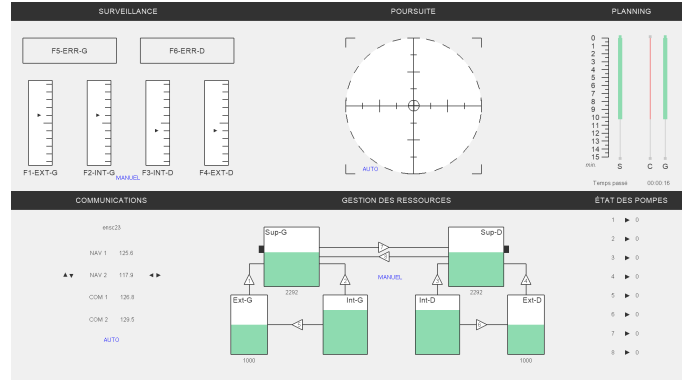


Fig. 1. Custom version of the OpenMATB interface used for the experiment

added (see the picture of the whole system in Fig. 2.). The subjects are asked to monitor and interact with the system if the failure of the system is detected.



Fig. 2. Experimental setting composed of two screens, one custom keyboard, one joystick and a headset

The subjects were aware that they will need to hand over during the scenario, however, is not aware how long the scenario goes and when the handover will take place. In certain conditions, the subject will need to prepare the handover while monitoring systems.

B. Subjects

Twenty-four participants (12 women and 12 men) took part in the experiment. Seventeen of them are aged between 18 and 25, 4 between 26 and 35, 1 between 36 and 45 and 2 for the rest of the age group. As for the evaluating how familiar they are with the aeronautical domain, we asked the subject to evaluate their expertise in this field. Ten of them have reported having unfamiliarity with the aeronautical domain, 14 have some experience (with flight simulations). All subjects have declared not been familiar with the MATB or similar interface. The descriptive data are presented in the table.

TABLE I
SAMPLE CHARACTERISTICS OF THE PARTICIPANTS

Familiarity with the aeronautical domain	
I have some notions	14
I don't have any notions	10
Age	
18 - 25	17
26 - 35	4
36 - 45	1
56 - 65	2
Sex	
Women	12
Men	12

TABLE II
EXPERIMENTAL CONDITIONS IN REGARDS TO THE AVAILABILITY FOR
HANDOVER PREPARATION AND SCENARIOS FOR EACH GROUP

	BOD	CFE
Group 1	With	Without
Group 2	Without	With
	CFE	BOD
Group 3	With	Without
Group 4	Without	With

C. Experimental Conditions

Each subject was assigned to experimental group depending on the available or not of the preparation for the handover (respectively “With” or “Without” preparation), and 2 scenarios. We have designed the scenarios around the airport of Bordeaux (BOD) and Clermont-Ferrand (CFE). We have made 4 groups of 6 subjects each. In order to confront a large scale of conditions with a small group of 24 participants, we have selected the most relevant conditions of the availability of the preparation (see Table 2.). Groups 1 and 2 went through the BOD and then the CFE scenario, while groups 3 and 4 went through the CFE and then the BOD scenario. The conditions of availability for handover preparation and scenarios have been counterbalanced to avoid any side effect.

At the beginning of the experiment, participants were given an introduction consisting of comprehensive written instructions on how to interact with the OpenMATB interface, a training session to comprehend the interface and two tasks scenarios. As the first step of the experiment, subjects were placed in front of the interface with a PowerPoint style tutorial to describe in detail the system. With this tutorial, the subjects learned how to operate the system, how the error occurs and what to do if it is the case. After the tutorial, follows the training session where the subjects could practice what they have learned about the system. At that moment, the subjects were set in the appropriate scenario, according to their experimental group. For the two main tasks, the subjects were asked to play the role of a remotely piloted aircraft operator in case of UAM. They would start with the ‘Bordeaux’ or the ‘Clermont-Ferrand’ Scenario. Those two scenarios were

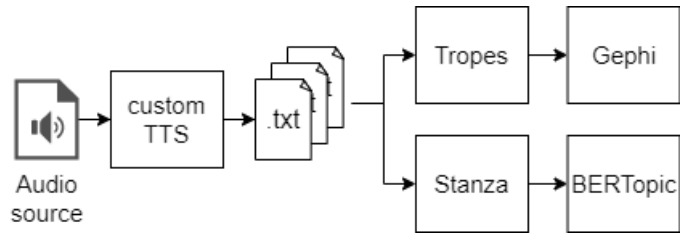


Fig. 3. Process diagram of semantic analysis from the symbolic and neural approach

similar in design and did not reflect any sign of differentiating factors in the experience. Prior to taking control of the system, subjects were briefly informed on the abnormal behavior reported for that particular aircraft during the day, followed by the mission briefing. During the scenario, subjects were asked to hand over their task by passing the instructions verbally to the experimenter.

D. Measurement and Data Preparation

The experiment gathered several behavioral measurements during the main tasks. The subjects were equipped with a microphone to record their speeches during their handover instruction. Handover information requirements are extracted through a specific process. To better understand what the relevant information is composing the subject’s speech that could reveal a generic layout, two different approaches have been used for the semantic analysis: (1) the symbolic content analysis with the software Tropes (specialized in French) [10] and (2) an approach based on neural topic modeling with BERTopic [11](Fig. 4). Those two approaches differ from each other by their methodology of content analysis. The former is based on syntax and semantic rules while the latter is based on pre-trained language model: Bidirectional Encoder Representations from Transformers (BERT) [12] and its derivative. Those two approaches have been selected according to their great quality in terms of results and analysis on extracting relevant topics in speeches. For the process, we have first gathered all the audio materials and convert it to texts. The conversion has been done from our custom developed Text-To-Speech software “pyInterviewTranscriber”. Then as for the symbolic approach, all texts have been analyzed by the software Tropes associated to a graph visualization with the software Gephi [13]. As for the neural approach, the texts have gone through a keywords extraction with the well-known Stanza library developed by the Stanford Natural Language Processing team [14]. Afterwards the keywords were analyzed across the BERTopic library and finally getting the visualization of the results.

Before going deep in the analysis of the topic modeling and topic progression, a bottom-up approach of building the semantic network according to all the current keyword has been set. The semantic analysis has been done based on the following semantic structure (Fig. 4).



Fig. 4. Process diagram of semantic analysis from the symbolic and neural approach

III. RESULTS AND DISCUSSION

Thanks to the audio recording device, we have collected experimental material for each condition. As the first step of our analysis, we collected all the data from the different scenarios, keeping in mind the experimental conditions, i.e. whether or not there was time to prepare for the handover.

A. Handover Instruction Speech

The number of words in regards of the “with” or “without” preparation in average seems to be very close, while its variability seems very high (Table 3). It seems that there is a great variability towards the inter-individual parameter of the number of words spoken during the handover. The subject’s speeches during their handover do not reflect the impact of the availability for the preparation of the handover (see the Table 4 for a summary of the different results of the comparative test with p -value greater $\alpha=0.05$). For that reason, the material gathered has been looking from a different angle.

The next table represents the material of the number of words from an intra-individual perspective (Table 5) – from each subject, it has been gathered the number of words according to the experimental conditions and the scenarios. In

TABLE III
DESCRIPTIVE STATISTICS FOR THE AVAILABILITY OR NOT IN TIME TO PREPARE THE HANDOVER (WITHOUT PREPARATION OR WITH PREPARATION) DURING THE HANDOVER INSTRUCTION

	Without preparation		With preparation	
	Mean	SD	Mean	SD
Words	138	103	154	94

TABLE IV
DESCRIPTIVE TABLE OF THE STATISTICAL TEST TO EVALUATE THE DIFFERENCE BETWEEN THE CONDITIONS ABOVE (WITHOUT PREPARATION OR WITH PREPARATION) DURING THE HANDOVER INSTRUCTION

First Sample	Second Sample	p-value
With	Without	0.2093
First handover	Second Handover	0.6957

order to highlight the difference from the first instance of the scenario (regardless of BOD or CLE), the ratio in terms of the following equation has been calculated: (number of words of the second scenario instance over the number of words of the first scenario instance). This ratio gives the tendency of the subjects verbalization compared between the two instances. According to the ratio of the Table 5, it would appear that the subjects were impacted by the “with preparation” condition on the second instance of the ‘BOD’ scenario as they have spoken more. On one hand, the ratio of the group 1 and 3 (with-without) indicates a tendency towards the reduction of the number of words along the instances of scenarios. On the other hand, the ratios of the group 2 and 4 (without-with) shows a leaning to the increase of the number of words along the instances of scenarios. Surprisingly, it can be said that the verbalization of the subjects in the condition of “with preparation” regardless to the scenario and time of the handover (first or second instance) seems to be greater than the “without preparation”. However as it has been demonstrated on the section above, no significant difference between the groups has been noted.

Those results could be explained by the following. While discovering the task and the interface in the first scenario, subjects were not able to know what could be relevant to share to another operator. It is for this reason that subjects have tended to describe all the interface in order to give to the next operator all the information from the past and current state of the system. The subjects seem to delegate responsibility for the rest of the task during the handover. Another possible reason for observing previous results is the operator’s familiarity with the system, which increases as the trials progress.

B. Semantic Analysis

Taking the number of words as the volume of relevant knowledge to share did not reflect any impact of the preparation time condition. For this reason, the semantic content of the handover instruction speech has been analyzed. With the help of the Gephi software for visualization in the graph and BERTopic Visualization, we have compared the topic

TABLE V

NUMBER OF WORDS FOR THE FIRST AND THE SECOND INSTANCE OF THE EXPERIMENTAL TRIAL ACCORDING TO THE CONDITIONS IN REGARDS TO THE AVAILABILITY FOR HANDOVER PREPARATION AND SCENARIOS FOR EACH GROUP

Group	Subject	First	Second	words ratio
With - Without / BOD - CFE				
1	1	195	97	0,50
	2	109	44	0,40
	3	68	154	2,26
	7	365	474	1,30
	9	192	123	0,64
	8	33	62	1,88
Without - With / BOD - CFE				
2	4	130	73	0,56
	5	264	242	0,92
	6	315	273	0,87
	10	33	92	2,79
	11	136	165	1,21
	12	55	98	1,78
With - Without / CFE - BOD				
3	16	45	68	1,51
	17	53	104	1,96
	18	149	128	0,86
	22	198	169	0,85
	23	69	58	0,84
	24	274	257	0,94
Without - With / CFE - BOD				
4	19	130	226	1,74
	20	56	7	0,13
	21	75	248	3,31
	13	33	48	1,45
	14	194	221	1,14
	15	157	176	1,12

modeling, and the progression of topics, depending on the conditions: “with” and “without” preparation. Thus the goal of using the semantic analysis is to extract what are the common relevant topics and what is their progression during the handover instruction.

1) *Symbolic approach:* To begin the semantic analysis the first step has been to apply the semantic structure as seen in the section above. Since the semantic analysis software is specialized in the French language, the graph results have been kept in the original language. The following results of the sub-section represent the content analysis with the Tropes software. Topic modeling Without preparation condition. The Fig. 7 shows the topics arranged spatially according to the frequency of their appearance in the subjects’ speeches in the “without preparation” condition. It represents the upper right frame where the topics are the most inter-connected with the highest frequency. It can be highlighted that the major concepts spoken during the handover instruction speech are the elements of the Task topic [Behavior, Monitoring, Tracking, Resource Management] (green node in Fig. 7), cognitive management topic [Risk, State] (blue node in Fig. 7), and the Context topic

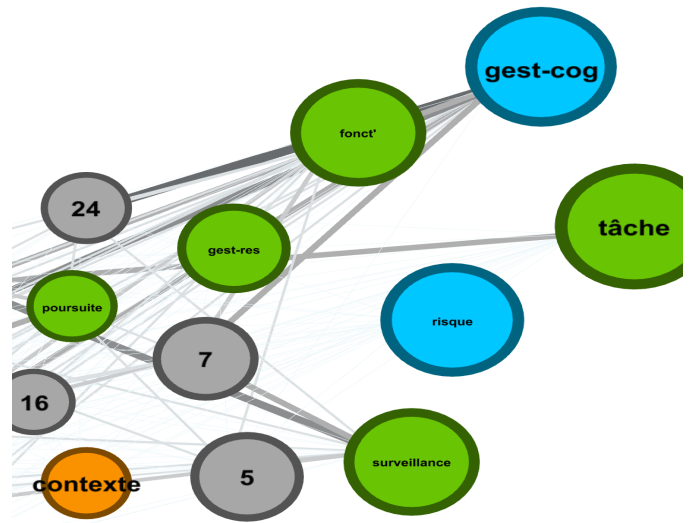


Fig. 5. Graph visualization of the topic modeling for the “without preparation” condition (gray nodes are representing the subjects; blue nodes represent the topics related to the cognitive management’ and the green nodes of the task topic)

[Mission, Location] (orange node in Fig. 7). The Fig. 7 also represents the subjects with gray nodes. More specifically, several concepts have a major link between the subjects and concepts such as the subject 24 with the concept Cognitive Management (gest-cog) or the subject 6 with the concept Monitoring (surveillance). That way the analysis reveals the more relevant topic but also the links that possesses the topic to the subjects.

2) *Topic modeling With preparation:* In the Fig. 8, the spatial organization of the topics in the “with preparation” condition seem to have changed compared to the “without preparation. The topics and the subjects are more inter-connected in the upper part of the frame. On that condition, we can find that the major concepts spoken during the handover instruction speech are the elements of the Task topic [Behavior, Monitoring, Tracking, Resource Management], Cognitive management topic [Risk] and the Context topic [Mission, Location].

3) *Topic modeling Handover summary:* Those topics have not differed between the handover “with preparation” or “without preparation” condition. However, displaying the topics associated to the subjects has shown a way to further analyze more in context. As the spatial organization of the of the topics is set based on the number of links that possesses a node, we can say visually that more subjects of the “with preparation” have greater connection to the topics than the subjects of the “without preparation” condition. It can be said that more subjects from the “with preparation” talk more often about the same topic and with a more variety of topics compared to the “without preparation” condition.

4) *Topic progression for without preparation:* We have highlighted the topic progression from the handover instruction speech of the subjects for the “without preparation” condition.

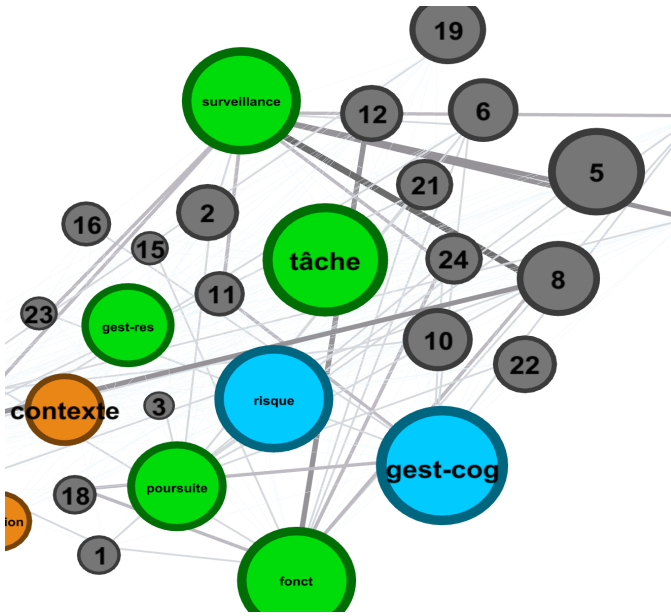


Fig. 6. Graph visualization of the ontology for the “with preparation” condition (gray nodes are representing the subjects; blue nodes represent the topics related to the cognitive management’ and the green nodes of the task topic)

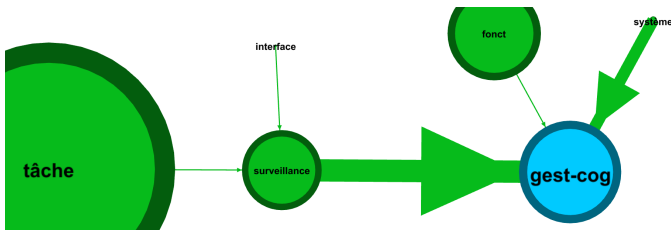


Fig. 7. Graph visualization of the topic’s progression based on the handover speech from the “without preparation” conditions

This topic progression is generated and steps are split based on the method of “episodes”. This method can detect when there is a break in the speech regarding the frequency of the topics. The result reflects that those elements such as Task, monitoring, behavior, risk, cognitive resources have a major impact according to their speech. This new way of visualizing based on co-occurrence of linked concept shows the generic layout from the “without preparation“ condition. Three main steps have been discovered: [Task, Interface], [Monitoring, Behavior, Systems], [Cognitive management].

5) *Topic progression for with preparation:* Regarding the way of visualizing based on co-occurrence of linked concept shows that in “with preparation” condition the following has been the generic layout. Three main steps have been discovered: [Systems], [Monitoring, Behavior], [Cognitive Management].

6) *Topic Progression Handover Summary:* Those results show generic layout of what the subjects are sharing during the handover instruction. We see some similarities on the way to express their situation. It seems that the concept that starts

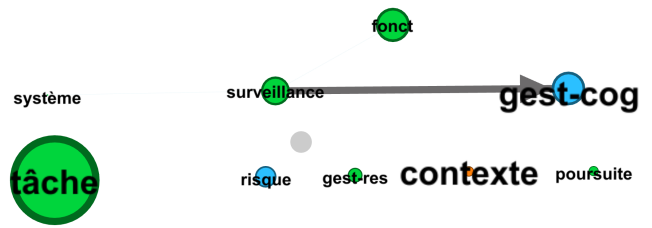


Fig. 8. Graph visualization of the topics progression based on the handover speech from the “with preparation” condition

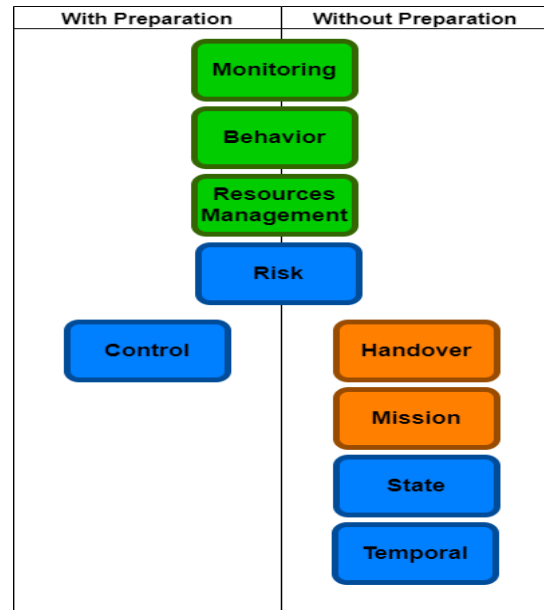


Fig. 9. Topic modeling based on Stanza and BERTopic content analysis depending on the “with”, “without” or common conditions

the speech is more often concepts about the task and their components. The topics ending the handover are topics related to the cognitive management. We can explain this behavior with the fact that naturally the first element that the subjects speak about is the last scene they see – their task. Thank to having their workspace in movement during the handover it helps giving a pattern with a degree of relevance from the more relevant knowledge to share to the least. As for the last concepts explained during their speeches, the subjects seem to finish on what is working or not for each task.

C. Neural topic modeling

To pursue the semantic analysis in the direction of extracting the most relevant topic and their progression we have used the Natural Language Processing approach. This analysis has been made with the help of the Stanza and BERTopic libraries. The upcoming results have been drawn manually based on the BERTopic Visualization in order to summarize the most common topics and the topic progression depending on the conditions.

1) *Topic Modeling Handover Summary:* The Fig. 10. represents the most common topics based on the handover speech

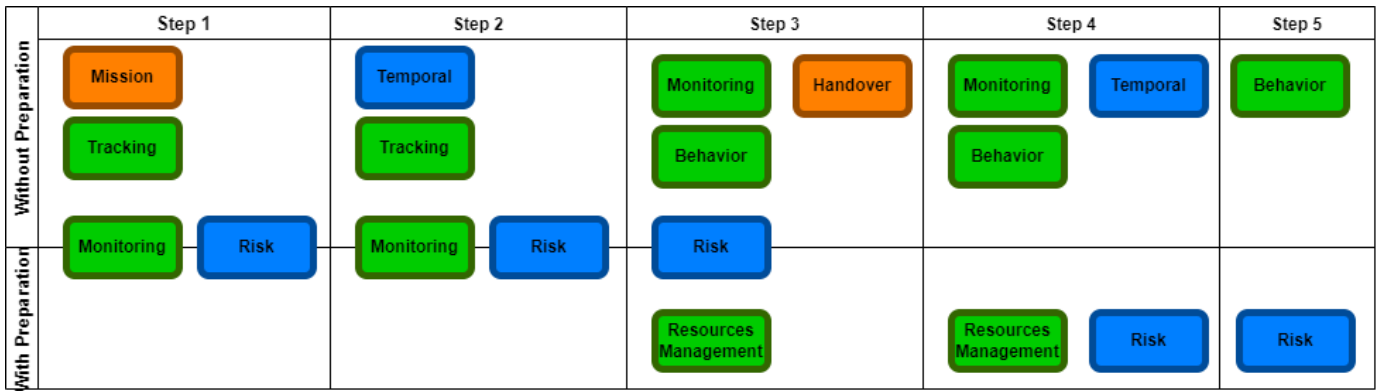


Fig. 10. Topic progression over time based on Stanza and BERTopic content analysis depending on the “with”, “without” or common conditions

of the subjects. The organization of the topics in the Fig. 10. does not represent any order on the different topic extracted from the handovers instruction. According to the results, it is possible to gather 3 groups: the topics that are in common regardless of the condition, the ones that are specific to the “with preparation” and those that are specific to the “without preparation”. All subjects seem to mention the topic related to the Task [Monitoring, Behavior, Resource Management]. While the “with preparation” condition reveals the following topics Cognitive Management [Control] and Task [Tracking], the “without preparation” shows topics related to Cognitive Management [Risk, State, Temporal] and to Context [Mission]. The “without preparation” condition seems to have in general two more topics, mention more topics related to Cognitive Management and to the Context. As for the “with preparation”, it seems that subjects were more concise in terms of variety of topics in their handover speech.

2) *Topic Progression Handover Summary:* To visualize the topic progression of the handover speech, we have represented the topics depending on their conditions of preparation. Since all handover speeches were unequal in regards of their length, we have split each handover on 5 steps that represent for each of them 20 percent of the speech. Globally, the topics that common over the handover are grouped under the first 2 steps: Task [Monitoring], Cognitive Management [Risk]. A repetitive pattern can be highlighted along the handover speech such as the topic related to Task [Tracking, Behavior, Monitoring, Resources Management], Cognitive Management [Temporal, Risk]. Specifically for the “without preparation” the topic progression analysis reveal that topics Context [Mission, Handover] and Cognitive Management [Temporal]. Finally, the “without preparation” condition shows a variety of topics highlighting the elements at beginning of the speeches with the context.

IV. CONCLUSION

In context for future air operation, this study offers an approach to identify different strategies for constructing the representation of the situation and for transmitting instructions to contextualize an operator. As a first step towards implement-

ing a dynamic method for the CROP approach, it is possible to assess not only the relevant elements of the context, but also the narrative progression of these elements in the discourse, using an information gathering analysis method. We could not draw any significant results from our early stage of analysis and report on the impact of handover preparation to enhance the handover speech. However, this first study is a basis for capitalizing on the information required from the handover. This material can then be used to generate a common model of handover specific to this simulation context. This essential step of knowing what the operator is thinking will enable us to calibrate pass situations synchronously involving two operators. Subsequently, it will be possible to design a study derived from the first involving a pair of operators. This next study will focus on the impact of standardization on operators’ understanding of the handover. In parallel of going further in the analysis of the semantic network, we think that this model could help us understand a generic layout and draw a topic progression for feeding our CROP approach. Those results show generic layout of what the subjects naturally are sharing during the handover instruction. At a higher level, our process tends to highlight minimal and relevant knowledge in the case of knowledge exchange. This methodology would need some adjustments to reflect more operational benefits and could be applied to use cases with experts’ population. That way, we could develop algorithms or feed the knowledge base for an automated assistant that mediates what is the relevant knowledge the operators need and what is the more suited order to share it. That framework could help the operator of future air operation to gain confidence in the contextualization stage and in maintaining a common frame of reference within a framework of exchange between two human operators or between a human operator and an artificial agent.

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