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Combat beyond visual range: a complex environment for decision-making

Combate más allá del alcance visual: un ambiente complejo para decidir

Combate além do alcance visual: um ambiente complexo para tomada de decisão

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ABSTRACT

The objective of this research is to evaluate how the complexity factors present in a *Beyond Visual Range* (BVR) combat arena influenced the achievement of situational awareness and the decision-making process of the F-5M pilots of the Brazilian Air Force (FAB). A field survey was carried out to analyze the perception of the 38 pilots present at EXOP BVR 1-2015. Based on these data, analyzes referring to the process of formation of situational awareness of Endsley (1995) were inferred to the universe of 52 operational pilots in combat with missiles beyond the visual range. The decision-making method of Rasmussen's (1982) marked the study of the responses of pilots, which focused on the SRK cognitive control model. The analysis of the results highlighted that the eleven factors of complexity showed to the 38 pilots undermined the formation of the situational awareness at level 3, since those hindered the future projections of the squadrons members actions in the arena. However, the same factors influenced the decision-making within the *Knowledge-Based Behavior* (KBB) model, which evidences actions based on previous knowledge.

Keywords: Complexity factors. Combat beyond visual range. Situational awareness. Decision-making

RESUMEN

La investigación tuvo el objetivo de evaluar de qué manera los factores de complejidad presente en un área de combate Beyond Visual Range (BVR) influenciaron en la obtención de la conciencia situacional y en el proceso de decisión de los pilotos F-5M de la Fuerza Aérea Brasileña (FAB). Fue hecha investigación en campo con la finalidad de analizar la percepción de los 38 pilotos presentes en el EXOP BVR 1-2015. Con base en estos datos fueron inseridos, al universo de 52 pilotos operacionales en combate con mísiles más allá del alcance visual, análisis referentes al proceso de formación de la conciencia situacional de Endsley (1995). El método de decisión de Rasmussen (1982) balizó el estudio de las respuestas de los pilotos que tuvo enfoque en el modelo de control cognitivo SRK. El análisis del resultado mostró que los once factores de complejidad presentados a los 38 pilotos perjudicaron la formación de la conciencia situacional en el nivel 3, pues dificultaron las proyecciones futuras de las acciones de los miembros de las escuadrillas en la arena. Con todo, los mismos factores influenciaron las decisiones dentro del modelo Knowledge-Based Behavior (KBB) que muestran acciones basadas en conocimientos anteriores.

Palabras clave: *Factores de complejidad. Combate más allá del alcance visual. Conciencia situacional. Tomar decisiones.*

RESUMO

A pesquisa teve como objetivo avaliar de que maneira os fatores de complexidade presentes numa arena de combate Beyond Visual Range (BVR) influenciaram na obtenção da consciência situacional e no processo de tomada de decisão dos pilotos de F-5M da Força Aérea Brasileira (FAB). Foi feita uma pesquisa de campo com a finalidade de analisar a percepção dos 38 pilotos presentes no EXOP BVR 1-2015. Com base nesses dados foram inferidas, ao universo de 52 pilotos operacionais em combate com mísseis além do alcance visual, análises referentes ao processo de formação da consciência situacional de Endsley (1995). O método de tomada de decisão de Rasmussen (1982) balizou o estudo das respostas dos pilotos que focou o modelo de controle cognitivo SRK.

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The acronyms and abbreviations contained in this article correspond to the ones used in the original article in Portuguese.

A análise dos resultados evidenciou que os onze fatores de complexidade apresentados aos 38 pilotos prejudicaram a formação da consciência situacional no nível 3, pois dificultaram as projeções futuras das ações dos membros das esquadrilhas na arena. Contudo, os mesmos fatores influenciaram as tomadas de decisões dentro do modelo Knowledge-Based Behavior (KBB) que evidenciam ações baseadas em conhecimentos anteriores.

Palavras-chave: *Fatores de complexidade. Combate além do alcance visual. Consciência situacional. Tomada de decisão.*

1 INTRODUCTION

Beyond Visual Range (BVR) combat requires pilots to prepare specifically for the complexity of the operating environment, which according to Perrow (1984), is external to the operator and lies in the context.

For Woods and Sarter (2005), the difficulty of operating an aircraft demands mental effort from the pilot when skills, abilities and cognitive knowledge are required. In the BVR flight, these situations are translated into the operation of the radar and in the understanding of the self-defense system – Radar Warning Receiver[1] (RWR), among other actions involved in this type of mission.

Woods (1998) states that complex environments can generate cognitive workloads and, thus, influence complex problem solving, degrading the operator performance.

The search for tactical improvements and the judicious use of medium-range BVR missiles brought the Brazilian Air Force (FAB) closer to others more developed by participating in exercises such as CRUZEX FLIGHT, RED FLAG, SALITRE, among others.

The General Command of Air Operations (COMGAR), aiming to improve these capabilities, in 2014, performed some specific Operational Exercises (EXOP) to promote the BVR combat flight among the F-5M Units.

The legal support for this improvement is present in the National Defense Strategy (END), which provides the use of shipped weapons systems […] that allow fire accurately and beyond the visual range (BRASIL, 2008, p. 29).

Failures can be summarized in the operation errors of the aircraft weapon system generated by the pilots themselves when the missile is launched. These errors led to the loss of armament efficiency in reaching the target. It is known that there are several factors involved in this environment which can change the final outcome of the mission.

The goal of a pilot in BVR combat missions is initially not to be shot down and, then, to validate a launch done by himself/herself. However, the complexity of the environment may influence the achievement of the most advanced levels of situational awareness, according to Schutte and Trujillo (1996).

One of the most complex moments of decision-making, within a BVR arena, for a fighter pilot is the launch of a BVR missile. For this, it is necessary that he/she has the understanding of the established situational awareness, which, according to Rasmussen (1982) and Reason (1990), takes place in the three levels of cognitive control.

In this way, the present work proposes to study the relationship between obtaining the situational awareness and the decision-making characteristics of the FAB F-5M pilots based on the influence of the complexity factors present in an operational flight with BVR capability.

2 CONTEXTUALIZATION OF EXOP BVR 1-2015

In this work, the researcher used the simulated scenario proposed and established at EXOP BVR 1-2015, which contemplated an arena divided in two territories. Two involved parties (called BLUE and RED) faced each other in scanning, escort and air defense actions.

The flights were carried out aiming at the training of the pilots in maneuvers that developed their abilities within a complex scenario for the formation of situational awareness and for the decision-making mainly at the moments of a medium-range missile launch.

The pilots took turns, flying on Offensive Counter Air (OCA) – BLUE country, or on Defensive Counter Air (DCA) – RED country, as well as taking turns as a leader and tactical wing in the formations in which they flew. In that way, the research gained credibility once all the pilots fulfiled distinct positions within the squadrons.

3 THEORETICAL FOUNDATION

An outstanding feature of a fighter pilot, during the course of a BVR flight, is the ability to make decisions in the face of various intervening factors.

There are three complexity factors pointed out by Woods (1998 apud HENRIQSON et al., 2009, p. 434), which will be studied in this research, namely: characteristics of the system, characteristics of the operators and characteristics of the interfaces. The **characteristics of**

[1] Radar Warning Receiver: Airborne equipment for the reception and alarm of electromagnetic emissions of radars of other aircraft or of ground radars.

the system are related to the dynamism of the process, the activity risk and the task uncertainties. In order to study the **characteristics of the operators**, it is necessary to know the number of operators and the hierarchy among them. The quantity and quality of the system's panels and controls reveal the **characteristics of the interfaces**.

In this research, all these characteristics were raised by experts of the Delphi method and presented in Chart 1. Those ones were inserted in the context of EXOP BVR 1-2015 and explored through questionnaires sent to the pilots, after the flights, to verify the influence in obtaining the three levels of situational awareness established by Endsley (1995).

The events in which the pilots took decisions, in this very context, were analyzed and guided by the cognitive control method of Rasmussen (1982) and Reason (1990).

For Endsley (1995), the improvement of situational awareness has been successful in training programs. Therefore, the flight context of EXOP BVR1-2015 was characterized as an ideal environment for quantifying the F-5M pilots training on combat flights with beyond visual range. missiles.

The formation of situational awareness is related to flight performance by three aspects: the pilot's needs, the information necessary for the perception to be measured and the maintenance of the environment to be studied, according to Endsley (1995).

The same author divides the situational awareness into three levels: perception, comprehension and projection.

At the level of perception (**level 1**), the pilot detects evidences and monitors the situation. At **level 2**, level of understanding, the pilot has the ability to understand the data and to interpret them. As to **level 3**, the pilot conceives an anticipation and makes a mental simulation to project future actions. It is called the level of projection, according to Endsley (1999).

The methodology for the study of the decision-making process was defined by Rasmussen (1982 apud HENRIQSON et al., 2009, p. 435), who explains the decision-making through three modes of cognitive control, known as the **SRK Method**. The cognitive demands related to the degree of great predictability and psycho-motor responses performed unconsciously are classified as Skill-Based Behavior (SBB). For routine situations where there is some training whose actions are taken based on rules or procedures predetermined in legislation, the authors classify them as Rule-Based Behavior (RBB). In the unusual situations whose actions are taken based on tacit or explicit knowledge, this process is called Knowledge-Based Behavior (KBB) (RASMUSSEN, 1982; REASON, 1990).

4 METHODOLOGY

The methodological paths will be clarified in this chapter as the research actions are traced on the studied phenomenon.

A field research was carried out during EXOP BVR1-2015. The technique used was that of the extensive direct observation which sought, through questionnaires, the data for the researcher's analysis (LAKATOS, 2001).

A survey was initially made based on the Delphi Method, with the intention of determining the complexity factors analyzed by the pilots. According to Shimizu (2006), that method is used to generate and clarify themes through collection of information and opinions of experts.

Shimizu (2006) states that the Delphi Method can be used for small groups. A questionnaire was, then, sent to two fighter pilots of the 1st/4th Aviation Group (1st/4th GAV) and two BVR flight controllers of the 2nd/6th Aviation Group (2nd/6th GAV). Two consultations were carried out in order to obtain the confluence of the responses, adjusting the collective judgment of those involved (SANTOS, 2001).

The Google Forms software was used as a way of disseminating these questionnaires. In the first phase of the method, the complexity factors that the four experts deemed important within a BVR flight environment were identified. After receiving those ones a matrix was prepared to be submitted to the second phase of the method.

At this stage, it was presented to the specialists to verify the relevance of the complexity factors.

For this, the calculation of the Coefficient of Concordance (Cc) of each of the presented values was used. Santos (2001) presents this calculation based on the Vn parameters (number of specialists in disagreement with the predominant criterion) and Vt (total amount of specialists). Santos (2001) also establishes a Cc of 60% or more for validation. This calculation was performed as per Equation 1 (SANTOS, 2001, p. 29).

$$Cc = (1 - Vn/Vt) \times 100 \quad (1)$$

The final matrix served to prepare a questionnaire that aimed to obtain from the pilots the perception about how the achievement of **situational awareness** and the characteristics of **decision making** are influenced by the **complexity factors** of a BVR flight.

At the end, eleven factors of complexity were tabulated and showed to the 38 F-5M pilots present at

the EXOP BVR 1-2015, in questionnaires shortly after the flights.

The inductive method was applied because, from the particular data verified by the sample, an inference was presented to the universe of 52 FAB operational in BVR combat F-5M pilots who were able to participate in the exercise. The minimum wanted sample of 34 respondents was considered for a 95% confidence level with a 10% margin of error, as recommended by Cochran (1965). For that, five situations were proposed in some stages of the flight.

Responses were divided into two phases. The first was focused on raising, through the convergence of the answers, how the listed factors of complexity influenced the level of formation of situational awareness. The same method was used in the second phase of the responses, as it sought to point out how the same complexity factors influenced the decision-making method of F-5M pilots.

The questionnaire was formulated as follows:

a) Questions 1 and 2 presented the complexity factors related to the interface. Data Link[2] information on the Tactical Situation Display (TSD)[3] screen, RDR range and Chaff[4] performance built the proposed scenario. Seeking the positioning of the pilots on the formation of situational awareness, the options were presented as follows: 1) I could only detect the positioning of the members of my squadron and the enemies on the RDR and TSD screen; 2) I could understand the tactics of my squadron and of the enemy squadron; 3) I could analyze the tactics of my squadron and enemy squadron, also predicting the future actions of most aircraft in the arena; and 4) None of the above.

In order to obtain the cognitive control method for launching a BVR missile, the options were arranged in this way: 1) I would make the decision to launch based on the information provided by the Data Link, by the RDR of my aircraft and on my personal quality of defining a good target; 2) I would make the decision to launch based on the information provided by the Data Link, by the RDR of my aircraft and in accordance with the provisions of the Order of Operations; 3) I would make the decision to launch based on the information provided by the Data Link, by the RDR of my aircraft and on my experience in several maneuvers similar to EXOP BVR-1, as well as on my knowledge acquired in the manuals on BVR combat of the FAB ; and 4) None of the above.

b) Question 3 presented the complexity factors related to the operators. Intense phraseology due to Data Link failure and high number of contacts in RDR. Seeking the pilots' position on the formation of situational awareness, the options were presented as follows: 1) I could continue in the combat, but only performing Flow Plan[5], without worrying about Shot Philosofy[6]; 2) I could continue in combat, but only performing Flow Plan and Shot Philosophy; 3) I could continue in combat performing Flow Plan, Shot Philosophy and planning all offensive actions settled in briefing, such as Opportunity To Strikers[7]; and 4) None of the above.

The obtaining of the cognitive control method of the pilots followed the same model of letter **a**;

c) Questions 4 and 5 presented the complexity factors related to the system. Intense phraseology the inability of the controller to inform the Threat Calls[8], risk of collision, arena with 16 airplanes, RDR screen saturated with contacts, Data Link failure.

The models for obtaining situational awareness and the method of cognitive control followed as the established in letter **b**.

Their responses were tabulated, classified and ordered so as to measure the perception of the group analyzed. A statistical treatment was established, since, according to Correa (2003), one can look for a trend of concentration of values of a given distribution. That is, whether it positions itself at the beginning, middle, or end of a certain distribution. This analysis used fad, as it demonstrates the data that most frequently occurs in a set (CORREA, 2003).

[2] Data Link: airborne system that allows data exchange between airplanes of the same formation, as long as they are connected in the same network.

[3] TSD: A digital display device, located on the aircraft dashboard, which shows to the pilot the tactical information provided by the navigation system, Data Link, among others.

[4] Chaff: metallic particles launched by aircraft to carry out countermeasures seeking to elude the radar of enemy aircraft and ground by forming a metallic cloud.

[5] Flow Plan: The flow plan of the fighter aircraft, within a BVR arena, determined by the tactical leader during the squadron briefing, in order to obtain tactical superiority in the area of conflict.

[6] Shot Philosophy: It is the plan established by the tactical leader during the squadron briefing in order to establish the timing and distances of the BVR missile launches.

[7] Opportunity To Strikers: message issued by the flight controller or tactical leader of the squadron that presents to the pilot the opportunity to shoot down an enemy aircraft which is about to drop bombs on the enemy country.

[8] Threat Calls are calls made by BVR flight controllers alerting to threats posed by enemy raiders whose are intended to execute defensive maneuvers on the part of pilots and thereby to compete for increasing chances of survival in the combat arena.

Chart 1 - Matrix of complexity factors.

QUESTION	COMPLEXITY FACTOR	DESCRIPTION
1 and 2	INTERFACE	GROUND/SHIPPED RADARS SUSCEPTIBLE TO CHAFF
		HIGH NUMBER OF CONTACTS IN THE F-5M BORDER RADAR
		LOW RANGE OF F-5M RADAR
		DATA LINK INFORMATION IN CMFD SCREEN
3	OPERATORS	PILOT/CONTROLLER INTERACTION DURING THE FLIGHT
		HIGH NUMBER OF AIRPLANES FOR A CONTROLLER
4 and 5	SYSTEM	RECEIVING THREAT CALLS AT THE RIGHT TIME
		BVR ARENA WITH MORE THAN 4 RED X 4 BLUE
		LOCATION OF FRIENDLY AND ENEMY AIRPLANES ON ARENA
		RISK OF COLLISION
		SATURATED PHRASEOLOGY

Source: The author.

Some restrictions were identified in the research and thus were classified as limitations. Initially, it was only possible to cover the group of fighter pilots who participated at EXOP BVR1-2015. There was also a limitation of the statistical method that only determined the concentration tendencies of the answers. Finally, the correlation between the failures in situational awareness levels and the classification of response errors were not analyzed, according to the SRK method.

The research, however, was relevant in that it can contribute to clarify the difficulties of the fighter pilots in the moments of greater complexity during a BVR flight and thus to indicate in what way the launches of medium-range missiles can be used in a judicious way through reducing the errors caused by the complexity factors of this environment.

5 PRESENTATION AND DISCUSSION OF RESULTS

The research was developed with the purpose of studying the relationship between obtaining **situational awareness** and the **decision-making** characteristics from FAB F-5M pilots through the influence of the **complexity factors** present in an operational flight with BVR capability. To this end a field survey was carried out, through a questionnaire submitted to the pilots who participated in Operation BVR 1, in the year 2015.

The representation of the sample obtained from 38 respondents, from a universe of 52 operational pilots on FAB BVR flights, reached a reliability level of 99%, with a margin of error of 10.95%, as recommended by Cochran (1965).

A statistical treatment was given to the research after tabulation of the data, since, according to Correa (2003), one can look for a trending of concentration of values of a given distribution. In this analysis, the fad was used, since it demonstrates the value which occurs most frequently in a data set (CORREA, 2003).

The questionnaires point out to the researcher the number of times (repetition) that respondents, when subjected to a certain problem, behave in relation to what has been presented to them (BRYMAN, 2004).

In the first phase of the questionnaire, as shown in Graph 1, the activation of the three levels of situational awareness was recorded, but the pilots concentrated their results on level 2. This prevalence indicates that all the complexity factors presented to the pilots prevented them from having means to conceive an anticipation and to make mental simulations to project future actions and thus to reach level 3 (ENDSLEY, 1999).

In questions 1 and 2, pilots could only understand the tactics of their squadron and of the enemy squadron, without having the ability to analyze and plan the future actions of most airplanes in the arena.

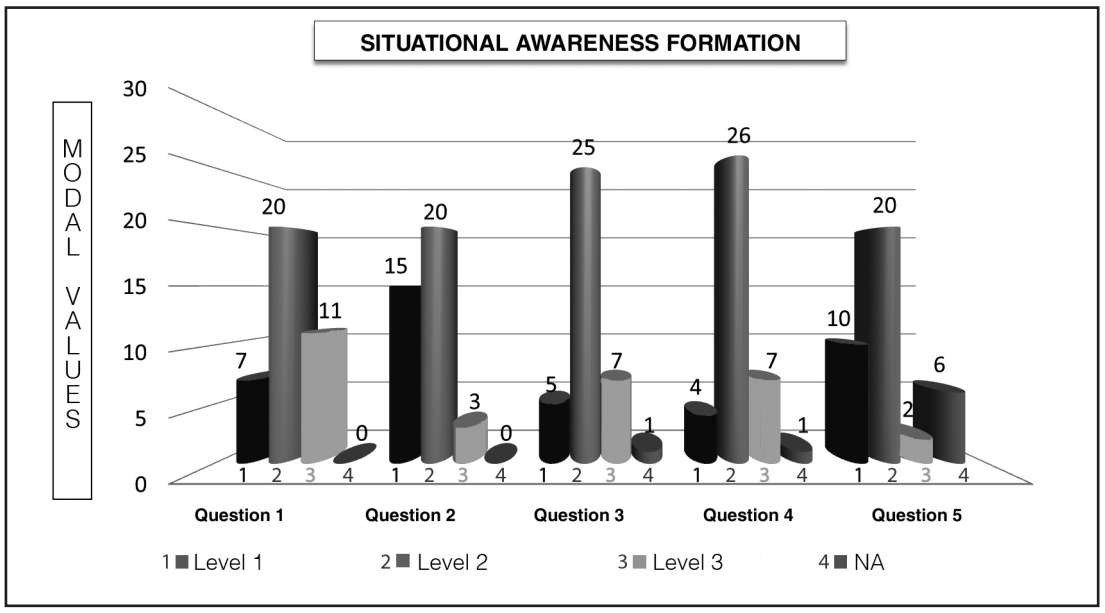
In the case of Questions 3, 4 and 5, the pilots would be able to continue in combat and perform Flow Plan and Shot Philosophy without being able to project the offensive actions settled in briefing, such as receiving an Opportunity To Strikers, engaging combat with this type of target and continuing to carry out Flow Plan and Shot Philosophy.

The difficulty found by F-5M pilots to obtain the level of projection can, then, be corroborated by Schutte and Trujillo (1996), who stated that the complexity of the environment can influence the attainment of the most advanced levels of situational awareness.

Endsley and Tilbury (2004) claim that the understanding of situational awareness is cognitively processed in the three levels of cognitive control of Rasmussen (1982) and Reason (1990).

Rasmussen (1982) defines that modes of cognitive control complement the approach to situational awareness levels defined by Endsley (1995, 1999). For Woods and Sarter (2005), the control decisions and actions are selected and activated from situational awareness. Such statements justify the study of the second phase of the questionnaire that clarified in which type of cognitive demand the responses of the pilots were concentrated.

Graph 1 - Modal values regarding the formation of situational awareness.



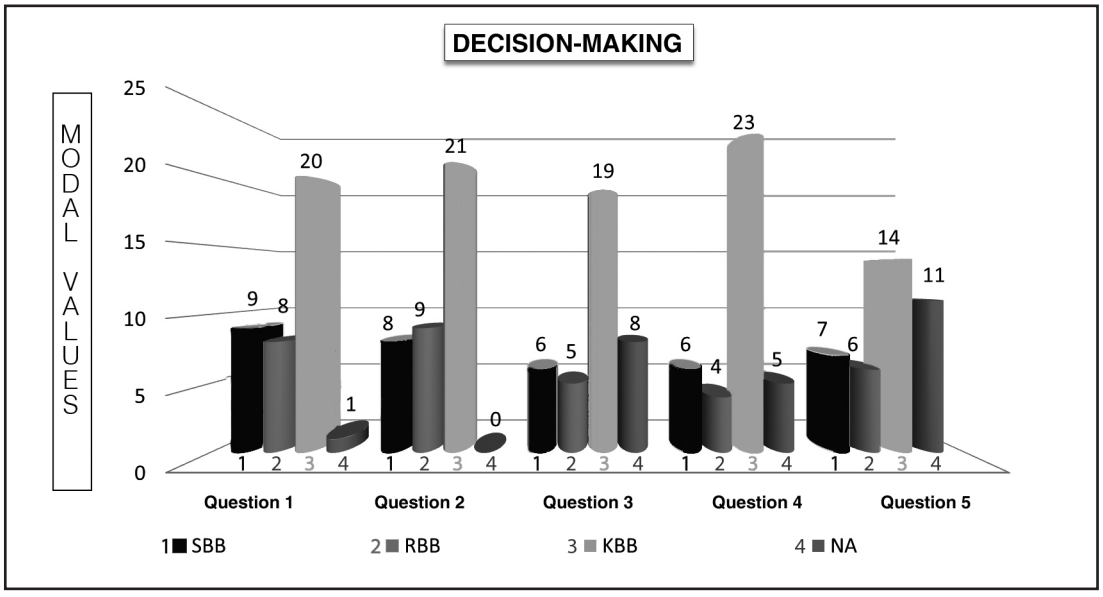
Source: The author.

In the second phase of the questionnaire, as shown in Graph 2, the pilots focused their results on Knowledge-Based Behavior (KBB) cognitive demand. This prevalence indicates that the eleven factors of complexity presented to pilots, based on unusual situations, enabled these operators to have the means to make their decisions in the BVR arena, based on tacit or explicit knowledge (RASMUSSEN, 1982; REASON, 1990).

The complexity factors presented in questions 1 and 2 generated situations of clear rules and greater knowledge of the pilots, such as operational RDR and Data Link, according to Rasmussen (1982, apud HENRIQSON et al., 2009 p. 435). At that moment, the answers had less spread among the alternatives, demonstrating a clear definition for the behavior in KBB.

In questions 3 and 4, some complexity factors, known to be difficult to be managed by pilots, such as Data Link failure and difficulty in receiving the Threat Calls were inserted and, according to Rasmussen (1982 apud HENRIQSON et al., p.435) represent rules that are not defined in manuals and require a representation abstraction at higher levels requiring stored knowledge of the pilots.

Graph 2 - Modal values of the types of cognitive demands.



Source: The author.

In question 5, the high number of aircraft in the arena, the need for greater altitude control and the Data Link failure were factors that generated the highest indecision degree of the operators as it can be seen in Graph 2. A large number of them chose for the None of Answers Above (NA) option. However, the prevalence in the KBB method was based on the decisions defined in the knowledge related to the situations previously trained and lived, according to Rasmussen (1982 apud HENRIQSON et al., 2009, p. 435).

The methodological approaches of this research focused on the complexity factors of a BVR combat arena within the process of situational awareness formation and the decision-making characteristics of an operational pilot on the F-5M aircraft.

Due to the predominance of level 2 situational awareness and the cognitive demand in the KBB method, it can be stated that the eleven complexity factors presented to the 38 F-5M pilots during the EXR BVR 1-2015 generated a restriction in obtaining the level of projection of future actions. However, they determined that pilots made their decisions at a high abstraction level, focused on previously known knowledge, based on previously trained and experienced situations, thus achieving the objective of the research.

6 CONCLUSION

The work began by addressing some characteristics of the complexity of the BVR environment and the specific preparation for fighter pilots.

Through the debriefings of EXOP 2014, there were some pilot failures in the final moments of the launch of a medium-range missile, generating their loss of efficiency.

It was decided then to focus the study on the formation of situational awareness established by Endsley (1995) and the method of decison-making of pilots defined by Rasmussen (1982 apud HENRIQSON et al., 2009, page 435) at the time of launching a BVR-capable missile.

These facts generated the concern to seek clarification on the relationship between obtaining **situational awareness** and the **decision-making** characteristics of the FAB F-5M pilots from the influence of the **complexity factors** present in an operational flight with BVR capability.

In the search for theoretical basis, the concept of complexity factors revealed to be applicable in the research, since it presents three aspects fully coherent with the BVR flight. In this sense, factors related to characteristics of the system, of the operators and of the interfaces were presented to the 38 fighter pilots present in EXOP BVR 1-2015.

The first research tool used was the Delphi method so that four specialists would raise the complexity factors of a BVR arena. The confluence of the responses and the alignment of eleven factors were achieved after two series of questionnaires.

As a consequence, a field survey was conducted, through a questionnaire presented to the 38 pilots of the sample after the flights of EXOP BVR 1-2015 to express their performances in the formation of situational awareness and to make their decisions according to the SRK method.

The information gathered from the first phase of the questions revealed that all eleven factors of complexity presented to respondents hindered the development of level 3 of situational awareness formation. With this, the projection of the future actions of the airplanes of the arena was impaired. According to the answers, the pilots could execute Flow Plan and Shot Philosophy, but they would not be able to receive a message from Opportunity To Strikers and engage with this target.

In the second phase of the responses, the pilots focused their results on the Knowledge-Based-Behavior (KBB) cognitive demand type. This prevalence demonstrated that decision-making, influenced by the eleven factors of complexity, was based on the tacit or explicit knowledge of the 38 fighter pilots.

In view of the facts presented, it is stated that, although there is a deficiency in the formation of situational awareness at the level of projection (level 3), by the majority of these pilots, the decisions were made at the highest level known by the SRK method. With this, it was defined that the pilots reached a high degree of abstraction based on previously stored knowledge.

In this way, the relationship between obtaining **situational awareness** and the **decision-making** characteristics of the FAB F-5M pilots was established based on the influence of the **complexity factors** present in an operational flight with BVR capability, being the objective of the research achieved.

As key lessons, it is envisaged that the clarification of the levels of the situational awareness formation obtained and the methods of decision-making can be used to modify the F5-M pilots training and the FAB EXOP preparation.

However, the improvement of the research that can be developed in other contexts, such as the Within Visual Range (WVR) arena, air-ground attack and close air support, among others, are suggested.

REFERÊNCIAS

BRASIL. Decreto nº 6.703, de 18 de dezembro de 2008. Aprova a Estratégia Nacional de Defesa, e dá outras providências. **Diário Oficial da União**, Brasília, DF, 2008.

BRYMAN, A. Qualitative research on leadership: a criticai but appreciative review. **The Leadership Quarterly**, v. 15, n. 6, p. 729-769, dez. 2004. Disponível em: <http://www.sciencedirect.com/science/article/pii/S1048984304000840>. Acesso em: 23 jun. 2015.

COCHRAN, W. G. **Técnicas de amostragem**. Tradução de Fernando A. Moreira Barbosa. Rio de Janeiro: Aliança para o Progresso, 1965.

CORREA, S. M. B. B. **Probabilidade e estatística**. 2. ed. Belo Horizonte: PUC Minas Virtual, 2003.

ENDSLEY, M. R. **Measurement of situation awareness in dynamic systems. Human factors.** Texas Teck University, 1995. p. 65-84. Disponível em: <http://uwf.edu/skass/documents/HF.37.1995-Endsley-Measure_001.pdf>. Acesso em: 06 jun. 2015.

_____. Situation awareness in aviation systems. In: GARLAND, D. J.; WISE, J. A.; HOPKIN, V. D. **Handbook of aviation human factors**. Mahwah, NJ: Lawrence Erlbaum Associates, 1999. p. 257-276.

ENDSLEY, M. R.; TILBURY, D. M. **Modular verification of modular finite state**. New York: Plenum Press, 2004. p. 972-979.

HENRIQSON, E. et al. Consciência situacional, tomada de decisão e modos de controle cognitivo em ambientes complexos. **Produção**, v. 19, n. 3, p. 433-444, 2009.

LAKATOS, E. M. **Metodologia do trabalho científico**. 6. ed. São Paulo: Atlas, 2001.

PERROW, C. **Normal accidentes**: living with high-risk technologies. Princeton, NJ: Princeton University Press, 1984.

RASMUSSEN, J. Human erros: a taxionomy for human malfunction in industrial installations. **Journal of Occupational Accidents**, v. 14, p. 311-333, 1982.

REASON, J. **Human error**. Cambridge, UK: Cambridge University, 1990. p. 302.

SANTOS, A. C. O uso do método Delphi na criação de um modelo de competências. **Revista de Administração**, São Paulo, v. 36, n. 2, p. 25-32, abr./jun. 2001. Disponível em: <http://www.rausp. usp .br/download .asp?file=v36n2p25a32.pdf>. Acesso em: 06 maio 2015.

SCHUTTE, P. C.; TRUJILLO, A. C. Flight crew task management in non-normal situations. In: HUMAN FACTORS AND ERGONOMICS ANNUAL MEETING, 40., 1996, Philadelphia. **Proceedings** ... Philadelphia: [s.n.], 1996. p. 244-248.

SHIMIZU, T. **Decisão nas organizações**. 2. ed. São Paulo: Atlas, 2006.

WOODS, D. D. Designs are hypotheses about how aircrafts shape cognition and collaboration. **Ergonomics**, n. 41, p. 168-173, 1998.

WOODS, D. D.; SARTER, N. Learning from automation surprises and going sour accidents. In: SARTER, N.; AMALBERTI , R. **Cognitive engineering in the aviation domain**. Hillsdale, NJ: Erlbaum, 2005.