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THE POTENTIAL USE OF VIRTUAL/AUGMENTED/MIXED REALITY FOR STRATEGIC LEVEL DECISION MAKING

by

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TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

Biography

Lieutenant Colonel Ismael Barrenechea is a Chilean Air Force Officer assigned to the Air War College, Air University, Maxwell AFB. He graduated from the Chilean Air Force Academy in 1995 as a pilot officer and Executive Engineering in Aeronautical Systems (Bachelor degree). In 2009, he graduated from Chile Central University with the degree of Civil Engineering. Finally, in 2017, he graduated from Chile's Air Command and Staff College with a Master's degree in Military Sciences.

After receiving his pilot wings, he specialized in fighters and bomber aircraft, having flown more than 3000+ hours. During his career, he has flown several aircraft including the T-35, T-37, C-101, Mirage M5-M, and F-16. His most recent assignment was Director of Air Operations in the International Air and Space Fair 2018 in Santiago, Chile.

Abstract

In the past 5 years, technologies related to Virtual Reality, Augmented Reality, and Mixed Reality (VR, AR, MR) have escalated their capabilities and usages far beyond games, reaching a broader range of applicability throughout society.. Senior military and business leaders should consider taking advantage of these technologies and using them at a higher level to improve the decision-making process.

This paper examines the potential use of VR/AR/MR at the strategic level of the organization to help the decision-making process in consideration of the shifting VUCA (Volatility, Uncertainty, Complexity, and Ambiguity), and JIIM (Joint, Interagency, Intergovernmental, and Multinational) environment that leaders have to deal with. The study presents a brief background description of the strategic thinking theory, definitions of the VUCA/JIIM environment, and some concepts of VR/AR/MR. Then, description of problems identified in relation to the so-far limited research on the use of these technologies at the strategic level is presented. The paper also addresses issues such as the underutilization and mistrust of those technologies (including associated demographic aspects), cognitive load theory vis-à-vis VR/AR/MR, and potential to address the challenges of management of too much information. The analysis section of this study uses the Analytic Hierarchy Process (AHP) to select key factors to be considered in the potential use of these technologies at the strategic decision-making level. Finally, the results expand those most important key factors, and provides recommendations for implementation in the present and the future.

INTRODUCTION

AR and VR are being used to innovate within countless training processes and procedures at the tactical and operational level throughout multiple civilian industries and military services among the armed forces. So far, the evolution of these systems has reached a fast pace, and growth projections are continuously increasing with abundantpositive feedback.[1] Moreover, the possibilities for expanding the use of these technologies are growing and the technologies can be easily molded to respond to more significant challenges at higher levels of decision-making.

Military organizations and particularly the Air Force have been at the leading edge of implementing innovations using these technologies.[2] However, the majority of the examples in the application of VR/AR/MR are found at the tactical and operational levels but not yet substantially realized at the strategic level. For example, one of the most advanced uses of VR in the USAF presently is Pilot Training Next (PTN).[3] This program has been underway for more than one year and has already produced new pilots who are training in a variety of major weapon systems.

The new challenges facing 21st-century strategic leaders who deal with the shifting VUCA/JIIM environment requires innovative and novel ideas. This research presents the idea of the potential use of these developing technologies to support the decision-making process at the strategic level. In order to understand the concepts involved in that idea, the paper presents a background in terms of what it means to lead at the strategic level in an uncertain world, incorporating strategic thinking theory, VUCA/JIIM definitions, VR/AR/MR concepts, and how they connect each other. Also identified are some of the key issues among the acceptance and

implementation of innovative technologies at higher levels of decision-making: highlighting the difficulties arising from the lack of development of these technologies.

In the analysis, the paper considers potential internal strengths and weaknesses, and external opportunities and threats. A comparison is made of all elements among each other:extracting factors such as adaptability, decision speed, TEMPO, information management, and equipment requirements as factors that contribute to answering the research question. Finally, the study expands those key factors in terms of how they fit into the decision-making process at the strategic level and how VR/AR/MR can leverage this process in in light of key recommendations.

Research question

This research paper uses a qualitative approach to answer the following question: how could technologies such as VR, AR, and MR be useful tools to help the strategic leader improve the decision-making process in the shifting VUCA/JIIM environments?

Problem background and significance

One of the challenges for a 21st-century strategic leader is continuous shifting of the environment. Leading at the strategic level in an uncertain world requires dominance of all tools available in order to be proactive among the VUCA/JIIM environment. The idea is to aim to make the most proper decision, having a clear awareness in consideration of the most significant number of factors surrounding those environments.

One of the foundations of the strategic leadership model is to build and lead teams as well as to lead through organizational change. Many of the changes and teams that modern organizations are facing involve novel ideas, mostly developed bottom up which is the trend

among the culture of innovation.[4] However, many of these innovations fail to reach the highest management level,[5] like the case of the use of VR/AR/MR at the strategic level.

There is a fundamental disconnect between the wealth of digital data available and the physical world in which it is applied. While the use of three-dimensional spaces is a possibility, the big amount of data available to inform decisions and actions remains trapped on two-dimensional pages and screens.[6] Moreover, the expenditure on hardware to equip Command and Control architecture is continuously increasing. Hence, if envisioning an ideal future using innovative technologies is something tangible, in the end, the use of VR/AR/MR could save resources.

For a strategic leader, in any organization, one of the greatest dangers is to interfere in operational or tactical decisions that should be handled at a lower level (micromanagement). However, sometimes bad strategic decisions have their cause in the ignorance of the information about what happens at those lower levels. Thus, systems such as AR and VR can help strategic leadership increase situational awareness and empathy with the organization it commands. In other words, give strategic leaders the capability to be "eyes on/hands off."[7]

Methodology

This paper employs a combination of the problem/solution and the scenario planning frameworks to provide a recommendation for any organization on whether to consider VR, AR, and MR technology utilization as a tool to improve the decision-making process, situational awareness, and shared consciousness at the strategic leadership level. The type of study is *descriptive* as it shows the strategic thinking theories, definitions of the new environments, and VR/AR/MR concepts along with evidence of some issues related to these new technologies. The analysis is *qualitative* since first, key factors are identified; second, they are compared; and

finally, the most influential ones are extracted to implement the technology at the strategic level. The above is developed using AHP (Analytical Hierarchy Process) as a tool. Finally, this research is *propositional* in that it recommends how to enact the most influential factors extracted from the analysis

BACKGROUND

As it was commented in the introduction through the problem background, most of the research works and applications of the new technologies related to Virtual and Augmented Reality have been oriented to the tactical and operational levels. The lack of research on using VR/AR in the field of strategic decision-making makes it pertinent for this paper to first explain, in condensed form, some foundational concepts on the subject. at the strategic level. In particular, concerning the theories of leadership and strategic thinking, what defines the VUCA/JIIM environment? And, finally, how can these attributes be affected by the concepts of Virtual and Augmented Reality?

Strategic thinking theory

Among multiple theories, the model of J. Browning[8] (also, the contributions of R. Hugues et al.)[9] explain some foundations of strategic thinking theory. The intention is not to explain in detail how each of these develops, but to emphasize the areas in which the use of the new technologies in question can be effectively applied.

According to R. Hughes et al., the definition of strategic leadership is: “Individuals and teams enact strategic leadership when they think, act, and influence in ways that promote the sustainable competitive advantage of the organization.”[10] Thus, the strategic leader needs to create processes, employ various systems to achieve an organization's competitive advantage, and exploit the organization’s potentials over time. Within these processes and systems lies the

process of technological innovation, where the use of new tools could improve the performance and interaction of individuals and teams in strategic decision-making.

In addition to the above definition, J. Browning argues that the strategic leader achieves sustained relevance and competitive advantage by establishing and applying three basic frameworks of work: goods or services, alignment with the external environment, and stability under pressure.[11]

In the first framework, (for the organization to deliver a high quality of goods or services) the strategic leader must apply a combination of leadership along with strategies and tactics that maximize quality, volume, and results (effectiveness), at the lowest cost (efficiency).[12] The U.S. Air Force Basic Doctrine defines strategy as: "the continuous process of matching *ends*, *ways*, and *means* to accomplish desired goals within acceptable levels of risk."[13] In this context, and applying Browning's first framework, it is possible to compare *effectiveness* as *the ends* — the degree to which the organization achieves the objectives set; and *efficiency* as *the means* — using the minimum of resources to produce the desired result. However, in this framework, *the ways* to achieve it are missing.[14] Here is where this research paper presents its primary focus, as the *effective* and *efficient* use and application of innovative technologies can be transformed into *the ways* necessary to complete the equation. Technologies such as Virtual and Augmented Reality can provide an additional tool for the strategic leader in making more accurate decisions and thus better satisfy the *stakeholders* and, at the same time, inspire the rest of the operational and tactical leaders of the organization.

In the second framework, the alignment with the external environment is a responsibility of the strategic leader, and his or her team, to continually monitor the shifting external environment to identify threats and opportunities.[15] Again, an essential factor that helps the strategic leader is adaptability to the ongoing changes in this environment. Maximizing the

potential of new technologies must begin with the team that supports the strategic leader and thus be more adaptive to the external environment.

The third and final framework referenced by Browning refers to stability under pressure. Today's swift environment produces inevitable surprises, which become almost the norm. The way an organization's strategic leaders handle a crisis determine their reputation and that of their staff. Therefore, the strategic leader and his team must be prepared to face a crisis. The better prepared the leader is for the crisis, the higher the chances for personal success and organizational results.[16] Thus, multiple training and crisis management tools have been innovated with the incorporation of VR/AR/MR. For example, VR immersion capacity[17] and low cost will allow leaders to train in aspects such as communication management, counseling, and decision-making under stress.[18] At the same time, AR could provide an ability to help the user have the necessary information, presented in the best way to optimize and streamline the decision-making process.[19]

In summary, the strategy is a plan, and strategic leadership is the thinking and decision-making required to develop and execute that plan. As Michael Guillot states, "Since the aim of the strategy is to link ends, ways, and means, the aim of strategic leadership is to determine the ends, choose the best ways, and apply the most effective means."[20] The above considers at all times the three frameworks described. From this foundation, a model can be formed that provides context for the essential and necessary elements of strategic leadership.

The model (figure 1) considers the external environment in which the organization exists, which is an environment that is continuously changing and affected by volatility, uncertainty, complexity, and ambiguity (the jagged outer lines). It continues with a description of the internal work of an organization for which the strategic leader is accountable.[21] Finally, with the correct

use of personal dimensions to execute the required work at the strategic level, the leader achieves success and thus gives the organization short-term credibility and legitimacy, as well as long-term vitality, viability, and survival.

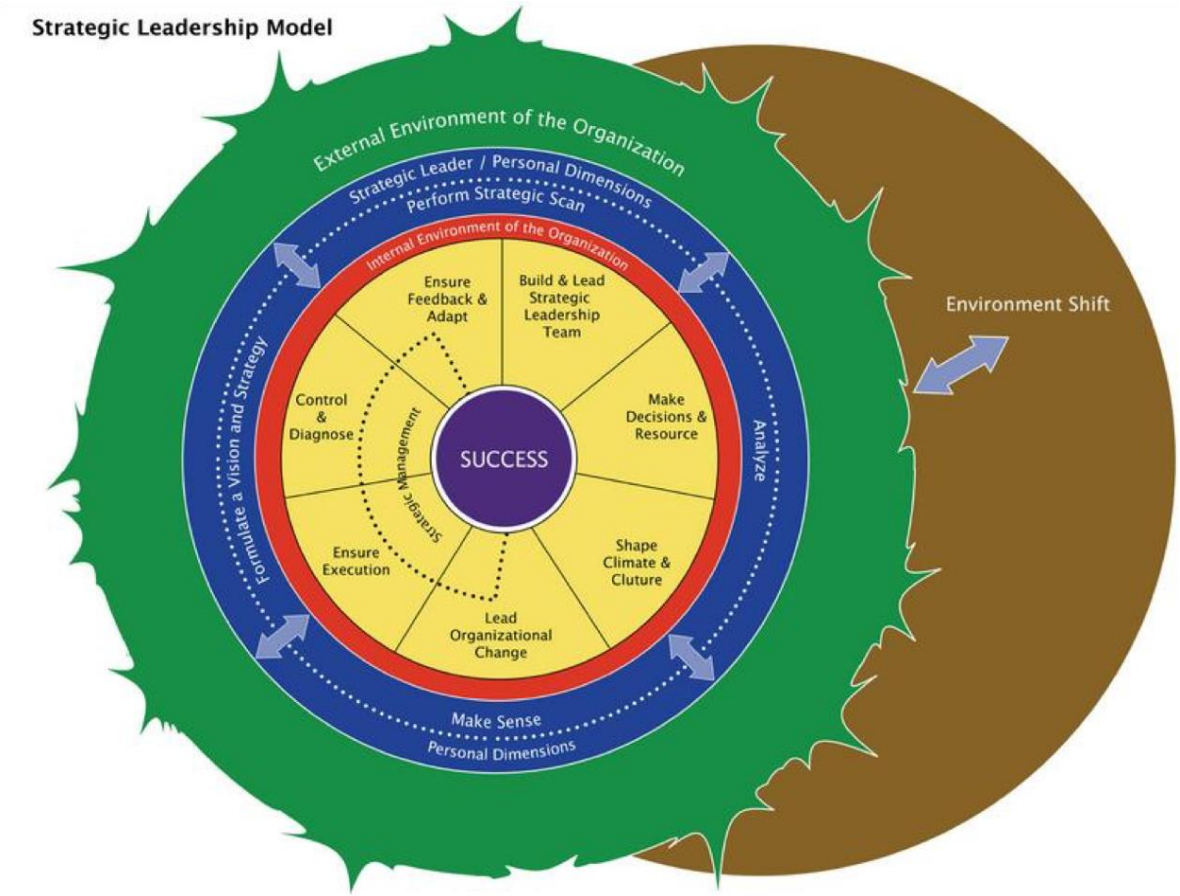

Figure 1 "Strategic Leadership Model"[22]

VUCA/JIIM environment.

Within the scope of this research work is the ever-changing external environment. One of the reasons why this environmental shift is given is by the fact that it develops within a Volatile, Uncertain, Complex, and Ambiguous (VUCA) setting. Also, all of the above occurs within the interaction of a Joint, Interagency, Intergovernmental, and Multinational (JIIM) domain. Therefore, the strategic decision-making process requires understanding this environment,

anticipating change, and managing risk. Thus, in responding to the challenges of the VUCA environment, first of all, it is necessary to understand the underlying implications that these terms represent.[23]

Volatility refers to the changing rate in the environment. In other words, even the most recent data does not provide enough context for decision-making. Rather than assessing the current environment, strategic leaders will need to anticipate rapid change and try to foresee what might happen within a given timeframe to an operation.

Uncertainty is the incapacity to know everything about a situation and the difficulty in predicting the nature and effect of the change. Uncertainty usually delays the decision-making process and compromises risk management.

Complexity refers to the difficulty of understanding the interactions of multiple factors and then being able to predict the effects of the change of one or more factors within a highly interdependent system or system of systems. Because of its nonlinear ramification, and its rapid multiplication of effects, complexity can create uncertainty due to the deviation of possible interactions and outcomes.

Ambiguity refers to a specific type of uncertainty coming from different interpretations when the contextual keys are insufficient to explain their meaning. Aspects such as cultural blindness, cognitive bias, or limited perspective create a diffused context that prevents interpretation of their meaning. At the strategic level, the chances of misinterpretation of events are high.

In the business field, the explanation of these concepts is similar and applicable to any organization, as summarized in figure 2 with examples of the concepts defined above.

Figure 2 "What VUCA really means to you"[24]

The concepts and organizations incorporated into JIIM are already known in general areas. However, it is important to emphasize that, in an organization, and mainly in a military one, the interaction with JIIM is directly proportional to the levels of leadership. That is to say, at the strategic level the interaction with JIIM is something mandatory, and on a daily basis, therefore VUCA and JIIM interrelate at all times.

Among the factors that influence the VUCA environment, are the explosion of technology and the magnitude of information.[25] It is known that technology changes daily and that the latest one day will be obsolete the next day. In this sense, this accelerated pace of

technological change makes it difficult to predict and accelerates the speed of operations. In the case of the magnitude of information, the management and interpretation of this is a permanent challenge for strategic leaders and their teams. The fast arrival of high volumes of information makes it difficult to keep everyone on the same page, increasing the complexity of the internal environment of the strategic leader. In other words, the fact that strategic leaders possess large amounts of information does not mean that it is accurate and relevant. It is at this precise point where the potential use of technologies such as VR/AR/MR could contribute to the set of skills required by the strategic leader to improve understanding of the environment, decrease risks, and make decisions.

Virtual, Augmented and Mixed Reality concepts.

After a brief review of the conceptual theory of strategic leadership, defiant and shifting environments, and decision-making models, it is necessary to understand the concepts of Virtual, Augmented, and Mixed Reality.

One of the most extensive publications regarding the design, implementation, and application of this type of technology is the *Handbook of Virtual Environments*[26] (The Handbook). This book serves as the primary reference for the definition of concepts used in this research. According to *The Handbook,* Virtual Reality is defined in the same way as Virtual Environment as: "a model of reality with which humans can interact, getting information from the model by ordinary human senses such as sight, sound, and touch and/or controlling the model using ordinary human actions such as position and/or motion of body parts and voice."[27]

In the same way, *The Handbook* defines Augmented Reality as: "a form of virtual reality where the human interacts with a combination of reality models and true reality, usually through the use of special eyeglasses displaying both data from the model and data from the real

world."[28] In other words, it can be defined as a set of technologies that superimpose digital data and images in the physical world.[29] Some sources describe AR as the cousin of VR and call it MR.[30] Then, considering that the MR environment is referred to as where people interact with digital elements as they move in the physical world,[31] for this research work, the concepts of AR and MR will not be differentiated.

In short, the core of the concepts described above is that these technologies will transform the way we learn and interact in the physical world. In other words, these technologies (especially AR) create a new paradigm of information delivery, where it is expected to have a profound impact on how data is structured, managed and delivered. The use of flat screens to transform data into information and deliver it has a major limitation, requiring people to mentally translate 2D information for use in a 3D world. AR allows processing both the physical and digital simultaneously, eliminating the mental effort to unite these two dimensions, which improves the ability to absorb information quickly and accurately for decision making and execute the required tasks more efficiently and effectively.[32]

PROBLEMS AND KEY ISSUES

With the aim of identifying the potential uses of these new technologies at the strategic level of an organization, especially a military one, some issues are identified. The limited research and therefore the poor implementation of VR/AR at the strategic level is one of them. It has also been detected that a low degree of confidence can be associated with a demographic aspect that currently drives decision-makers at these levels. Vulnerabilities in the information age and the concept of too much information are other difficulties that need to be addressed.

Underutilization.

Performing a simple search by the most popular Internet search engines, library websites and one of the most used search engines in academic publications such as Google Scholar,[33] and looking for “virtual+reality+for+the+strategic+level,” “augmented+reality+for+strategic+level,” and other combinations emphasizing this topic, it is observed that the results are very scarce, not directly related, and almost zero. However, if this search is modified to a lower level such as operational or tactical, the results are plentiful. Likewise, in the fields of distance education, crew training, and work teams, among multiple other disciplines, research, and the current use of immersive technologies, or as defined in the Handbook of Virtual Environment "presence,"[34] results are plentiful in number.. Some examples of this include the basic flight training beta test with VR carried out by USAF with undergraduate pilots called Pilot Training Next.[35] Also, in the field of medicine there is high use of VR/AR in multiple procedures and with very recent publications in research on the subject.[36] In manufacturing, Boeing is very advanced in the use of AR,[37] and companies such as Walmart use VR to train their employees to assume tasks in various departments.[38]

So, what is the reason for the lack of use of these systems at the strategic level? First, in the case of VR, research and development has mainly targeted the field of education altogether at the tactical and operational level. Because VR gives the possibility to interact and react as if the user was in the real world, on the surface, it seems as though VR offers a simulation fitted more for tactical and operational training.[39] Therefore, making the case for using VR to make decisions at the strategic level can be challenging since VR represents a world which is not real. In the case of AR, however, one of the reasons that may justify underutilization is that it is considered a very new technology and currently is at an emerging stage.[40]

Mistrust of new technology.

It has been known for many years that technology helps to better manage the vast amount of information for decision making. However, the lack of skills in the use of these tools can cause problems and lead to mistrust in them. Phrases such as: "these new systems are very complex, I'm too old to start learning them now," "I've tried it once, and it didn't work for me; the system doesn't like me," "I'm from the old school, if it worked before, why not now?" are typical within senior strategic leaders and reflect the mistrust mentioned.[41]

One aspect to consider in the implementation of new technologies is adaptability and confidence in the use of these technologies. As people are promoted to higher ranking and strategic positions within an organization, the amount of information they must manage increases as well. In addition, the complex and changing environment demands cognitive abilities that a strategic leader must have to process this massive amount of information in a fast and efficient way to effectively make decisions. Technologies such as VR/AR have a high potential in the field of facilitating the visualization of information, cooperating with the concepts of load and cognitive distance.[42]

Vulnerabilities in the information age.

For any organization, with cybersecurity is paramount to protect its information and employee privacy. Moreover, in military or government institutions, security breaches can compromise classified information and national interests. For this reason, new wireless technologies, especially AR, require more advanced protocols in order to operate. The multiple possibilities that VR/AR grants for the visualization of information, and to interact directly with other people across the world as if they are in the same room (such as in VR/AR telepresence), are able to work with standard home Internet speeds (1-3 Mbits/sec) and even through the

corporative firewalls.[43] Now, the idea is to leverage the capabilities and developments achieved by industry with these technologies, providing the necessary protection, but in a way that does not mean a slowdown of these accomplishments.

In the case of handling too much information, besides the cybersecurity problem described above, there are issues concerning its administration and interpretation. Strategic leaders need to know what deserves enough attention, and what should be discarded. Too much information can overwhelm or delay decision-making; in some cases, information overload can lead to paralysis,[44] becoming a great vulnerability. Hence, the use of VR/AR comes to support the Data-Information-Knowledge-Wisdom (DIKW) model[45] that supports decision-making, in this case, the strategic decisions.

ANALYSIS

The objective of the analysis of this research paper is to identify the key factors, compare them, and extract the most influential ones to be considered in the recommendations and conclusions of the study. In order to achieve this objective, the systemic SWOT[46] tool is used.

The procedure for applying this tool is described as the steps below are performed.

Key Factor identification.

Considering the potential use of VR/AR for decision making at the strategic level, internal (Strengths-Weaknesses) and external (Opportunities-Threats) factors have been determined, according to the literature review and research conducted. Figure 3 shows the selected factors.

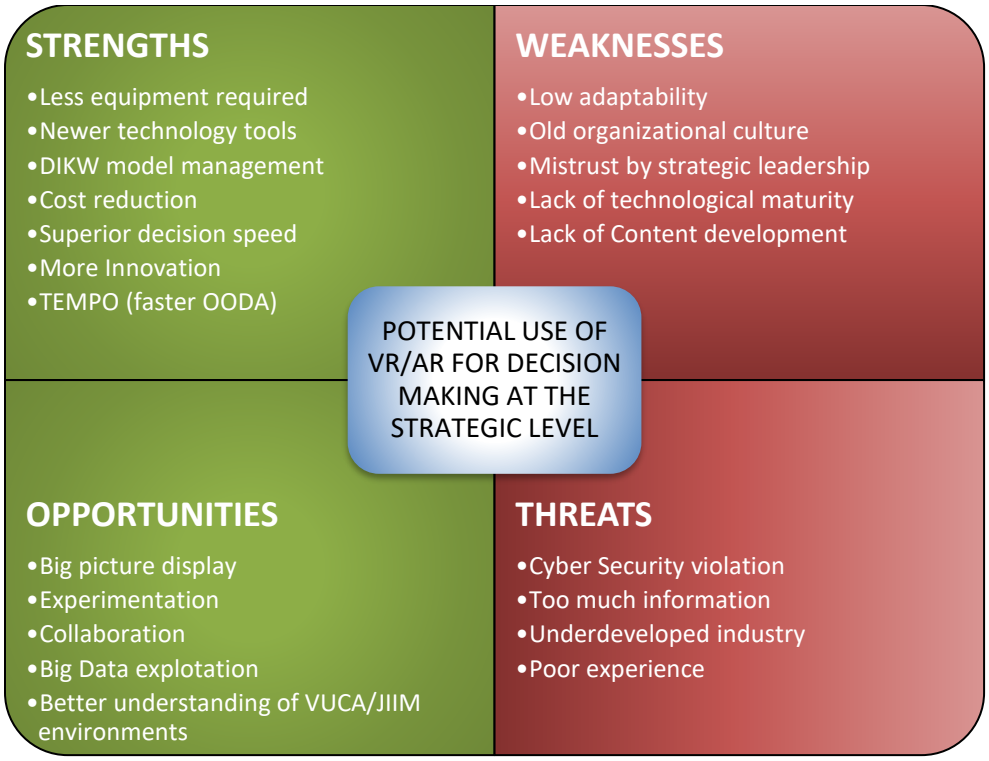

Figure 3 “VR/AR SWOT strategic level decision making”

Having identified all these factors, and aiming to simplify the analysis, the number of these factors is reduced by selecting the most important ones. This selection is then neutralized by eliminating positive or negative appraisals, as shown in Table 1.

Most important factors	Neutralization
Less equipment required	Equipment requirement
Cost reduction	Cost
Superior decision speed	Decision speed
Low adaptability	Adaptability
Mistrust of the strategic leadership	Leadership confidence
Lack of technology maturity	Technological maturation
Faster OODA loop	TEMPO
Better understanding of VUCA/JIIM environments	New environment understanding
Big Data exploitation	Big Data exploitation
Cybersecurity violation	Cybersecurity
Too much information	Information management
Underdeveloped industry	Industry development

Table 1 “Most important factors and neutralization”

Comparison of key factors.

Having now neutralized the most important factors identified, the influence matrix is elaborated. This matrix assesses the ability of each factor to influence the other. The idea is to ask the following questions: Is there a direct influence of factor A on factor B? If the answer is "NO," it is recorded with a 0 (zero) in the corresponding field, if the answer is "YES," proceed to the next question: is this influence intense, medium or weak, then 3, 2 or 1 is recorded in the corresponding field, respectively. The influence of a factor itself will not be investigated. Finally, for the influence analysis, one should always start from the current state, not from a future, desired or imaginary situation.

Upon completing the corresponding fields of the influence matrix, the numbers are added vertically and horizontally, and the following is obtained for each factor:

Active Sum (AS): Indicates the intensity of the influence of the factor in the overall system in relation to the others.

Passive Sum (PS): Indicates the (relative) intensity that the other system factors have over the factor.

The last line of each factor contains the *AS* and *PS* product. For the next step, it will help to draw the effects structure.

	INFLUENCE IN / INFLUENCE FROM	A	B	C	D	E	F	G	H	I	J	K	L	∑ AS
A	EQUIPMENT REQUIREMENT		3	2	3	0	2	0	0	3	3	1	3	20
B	COST	2		0	2	1	1	0	0	0	2	0	0	8
C	DECISION SPEED	1	0		1	0	0	3	2	2	2	2	0	13
D	ADAPTABILITY	2	1	3		3	0	2	2	0	1	2	0	16
E	LEADERSHIP CONFIDENCE	2	0	2	1		0	2	0	0	3	0	0	10
F	TECHNOLOGICAL MATURATION	3	1	2	3	3		2	0	2	3	2	2	23
G	TEMPO	1	1	3	3	1	0		3	1	0	2	0	15
H	NEW ENVIRONMENT UNDERSTANDING	0	0	2	3	3	0	3		2	0	1	0	14
I	BIG DATA EXPLOITATION	1	0	2	1	1	1	2	2		0	3	0	13
J	CYBER SECURITY	1	3	2	2	3	2	1	1	3		3	1	22
K	INFORMATION MANAGEMENT	1	1	3	2	2	1	2	1	3	0		0	16
L	INDUSTRY DEVELOPMENT	3	3	1	2	1	3	1	0	3	2	1		20
	∑ PS	17	13	22	23	18	10	18	11	19	16	17	6	
	AS x PS	340	104	286	368	180	100	180	110	190	160	170	60	

Table 2 “Influence matrix”

With the matrix completed, the data are available to develop the effects structure. This is a graphical way of visualizing the data from the matrix, showing the intensity and course of the individual effect currents.

The factor that shows the largest product of *AS* and *PS* is selected; it gathers the most significant number of incoming and outgoing effects flows, and it is located in the center of the table.

In this case "ADAPTABILITY" is the factor that obtained more product; from a simplified manner it is possible to begin to obtain the first interpretations of the analysis. However, it is necessary to combine the graphical results to obtain a better visualization. For this case, figure 4 shows the structure of direct effects obtained from the interpretation of the matrix. The red arrows represent a strong influence, the blue ones an intermediate one, and the green ones a weak one.

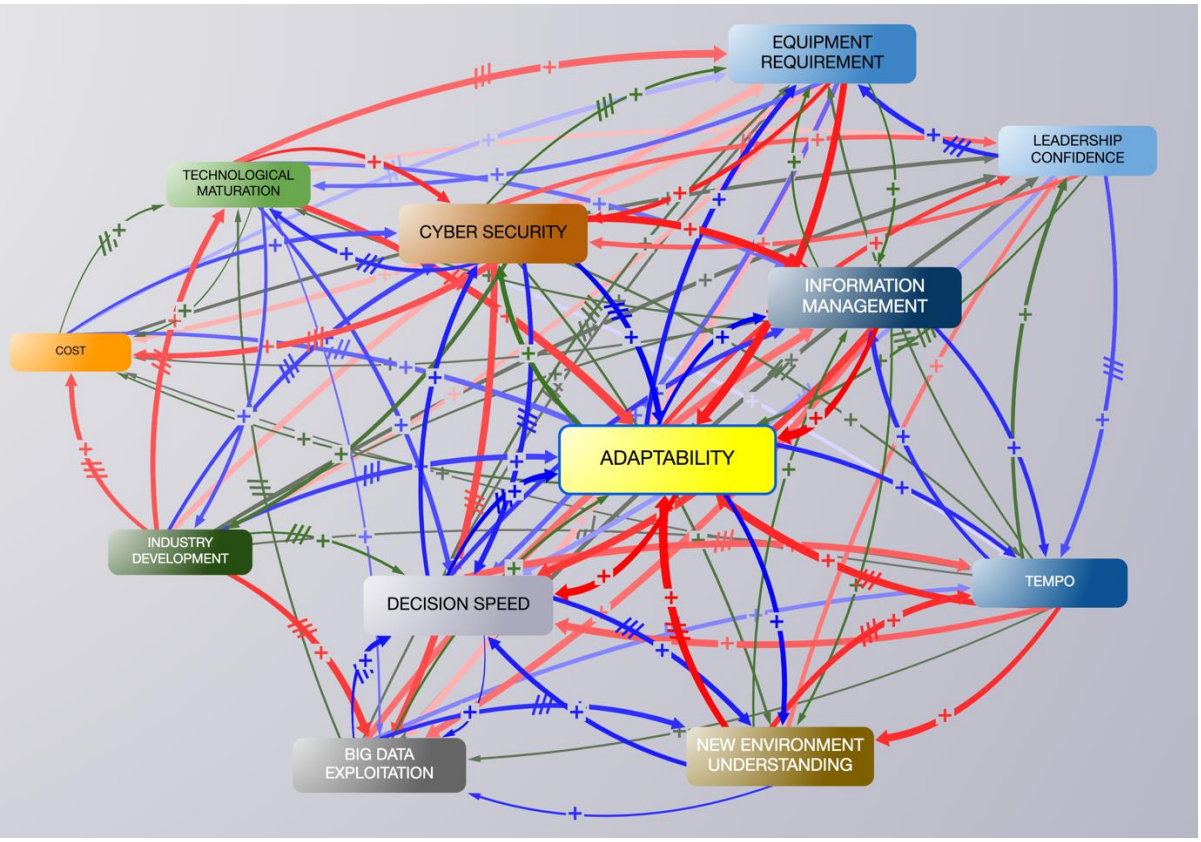

Figure 4 “Effects structure”[47]

Returning to positive and negative assessments of factors before neutralization, one could analyze the direct and indirect effects of one factor on the other; in this case only the direct effects are shown. Due to the number of factors combined, the structure becomes more difficult to interpret visually, which is why it will be necessary to make an axial diagram that gives a more straightforward interpretation.

The axial diagram provides additional information: the relative intensity of the influence of each factor, in comparison with the other factors and with the relative degree of "sensitivity" (Influenceability) of that factor affected by the system. The AS and PS of each factor of the Influence Matrix allow us to create a coordinates system in which a position is assigned to each factor. The *X*-axis is used for the *AS* and the *Y*-axis for the *PS*. Both axes have the same measurement determining their respective quadrants. According to the *AS* and *PS*, subsequently,

the numbers corresponding to both axes will be assigned. This diagram will determine the relative intensity of each factor.

The procedure is as follows, the maximum *AS* of the Influence Matrix is recorded at the outermost location of the *X-axis*. From here on, all other graduations of the scale are assigned with the corresponding numerical values. The *Y-axis* proceeds in the same way with the *PS*. Then each factor is recorded in the coordinates system. The cross formed by the axes creates a division into 4 quadrants which help to divide the set of approximate shape factors, and in which these have an influence on other factors and are influenced by the others. Quadrants are:

- Active (intense influence, low influenceability).
- Passive (low influence, high influenceability).
- Critical (intense influence, high influenceability).
- Inert (low influence, low influenceability).

Figure 5 shows the axial diagram of the influence matrix according to the selected factors.

Figure 5 “Axial diagram”

The upper left quadrant (Passive) contains the *Cost* and *Leadership Confidence* factors, representing that they are mainly dependent on the other factors, but fail to influence them in return. In the lower left quadrant (Inert) there is no factor, i.e., there are no factors that are dependent and influenceable at the same time.

The right lower quadrant (Active) contains the factors *New environment understanding*, *Technological maturation*, and *Industry development*, and represents the factors’ low dependency on the other factors and the capability to influence them at the same time. That is to say, according to the system that is being analyzed, it is difficult to control these factors since they usually are external elements.

Finally, the upper right quadrant (Critical) contains the factors *Adaptability*, *Decision speed*, *Big Data exploitation*, *TEMPO*, *Information management*, *Equipment requirement*, and

Cybersecurity, representing a significant influenceability and dependency at the same time. That is to say, a variation in the positive and negative evaluations of these factors can have an important repercussion on the system in general.

Factors to be considered.

To select the factors that should be considered for this study, it is time to return to the initial question that guides it. How could the employment of VR/AR technologies be a useful tool that helps the strategic leader improve the decision-making process? To answer this question, one must return to the initial SWOT analysis and compare it with the results obtained in the influence matrix, effects structure, and axial diagram. The procedure is described below.

According to the scope of this research and in order to simplify the results of the analysis, we first determine the internal factors of the organization, i.e. strengths and weaknesses, then we consider the factors that have the greatest capacity to influence others, i.e., those on the right side of the axial diagram (critical and active quadrants).

This results in, for this study, the final key factors that strategic leadership should consider in employing tools (such as VR/AR/MR) to assist in the decision-making process. They are: *Adaptability - Decision speed - TEMPO - Information management - Equipment requirement*.

RESULTS AND RECOMMENDATIONS

In order to complement the answer to the research question in this paper, each of the 5 key factors obtained after the analysis is justified in detail below. Within this justification, appropriate recommendations are added.

In the original SWOT table, *Adaptability* figured among the weaknesses referring to "low adaptability." However, as a general concept, adaptability is a skill that is generally associated

with flexibility, referring to the degree to which adjustments are possible in practice, processes or system structures to the projected or actual changes in conditions or circumstances.[48] In this sense, the importance of this factor is justified by the incorporation of a new way of interacting with the available technology, e.g., taking it to physical locations designed for other purposes (offices, meeting rooms, classrooms, CAOC, etc.). Another important aspect is the one mentioned in John Boyd's "organic command and control" theory, where he emphasizes adaptability over technological dependence.[49] Nonetheless, one of the positive aspects by which technologies such as AR are characterized refers precisely to its adaptability, and the potential support it gives the leader to recognize changes in the environment quickly.[50]

As a recommendation, it is necessary to consider first that the capacity provided by AR and its adaptability must be compatible with the ability of the strategic leader to adapt it to physical locations where he/she previously received information by other means, such as paper or 2-dimensional screens. Secondly, considering the changing VUCA environment, this leader must rely on VR/AR/MR technology to scan and make sense,[51] thus connecting the points that help him/her to foresee a strategy in the decision-making.

The *Decision speed* factor comes from the fortress defined as "superior decision speed."[52] From the cognitive point of view, this factor acquires greater relevance as it is assumed at the strategic level of an organization. The possibilities offered by VR/AR/MR to improve decision speed are real, especially concerning the concept of "cognitive load"[53] explained earlier in this paper. Uncertainty and incomplete information are realities within any organizational crisis and even moreso in war. Strategic leaders must be able to make sound decisions at a faster pace than the adversary. The opportunity to access Big Data exists; however, the physical and cognitive ability to integrate it into useful information is limited. VR/AR/MR integrates information as a

human-machine interface that delivers correct information at the right level of detail to the leader who, through his knowledge and experience, can make the right decision.

For the *Superior decision speed* to become a reality, it is recommendable to start thinking from now on about the content, systems, and applications in which the VR/AR ecosystem will need to manage a large amount of data, transform it properly into information, and deliver it clearly to the decision maker. An excellent example of this vision appears in the Air Force Future Operating Concept (2015), which explains the concept of *User-Defined Operating Picture* (UDOP) and the idea of becoming an interface between the decision-maker and the *Common Operating Picture* (COP).[54] AR represents an ideal tool for this scenario.

The *TEMPO* factor initially corresponds to the strength of having a fast OODA loop, which contributes directly to the above factor in terms of decision-making capacity. USAF's Air Combat Command, through its Operating Concept for Combat Cloud 1.0, states that: “The desired end state is to achieve DS (Decision Superiority) for Commanders, Senior Decision Makers, and Operators in order to conduct effective combat operations in the most taxing current and future threat environments. DS is the process of making better decisions arrived at and implemented faster than an opponent can react.”[55] Therefore, having the tools to better manage this OODA loop, precisely at the strategic level, is a significant advantage. In this sense, systems such as MR can help the strategic decision maker to have a better and faster understanding of the scenario, which, as described in previous sections, is characterized by its VUCA/JIIM environment. Especially in the military environment, where strategic leaders must consider multi-domain operations, the speed of a single OODA loop is not sufficient. It is necessary to manage multiple OODA loops as shown in figure 6.

Generally speaking, the winner is not necessarily the one with the fastest OODA loop. Rather, the one that has the ability to manage multiple OODA loops, using a large amount of information in them, improving the *Situational Awareness*, oriented to the analysis of decision-making.[56]

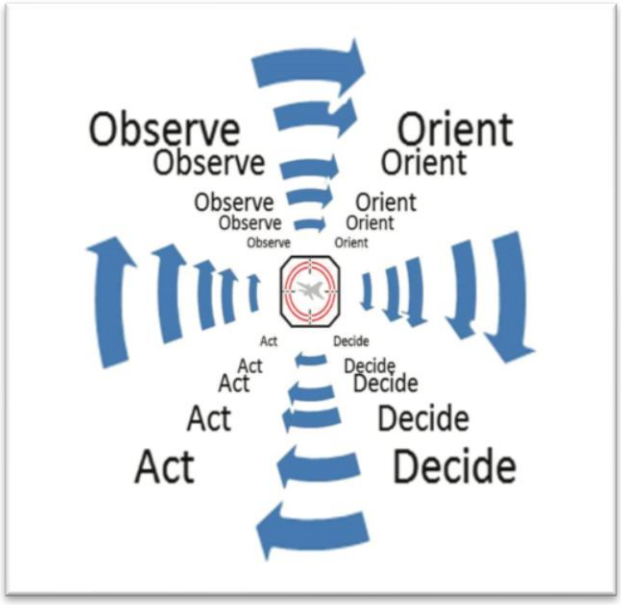

Figure 6 “Multi-Domain Fusion Warfare OODA Loops with Decision-Making Analysis”[57]

A glowing and straightforward recommendation in the field of *TEMPO* is related to the trend of new organizations to leverage and foster the use of new technologies that allow the strategic leader to have better decision cycle management (OODA) in an environment characterized by multi-domain.

The information management factor, which comes from the "DIKW model management" strength, is closely related to the factors mentioned above and is described in the same way. However, it is said that 90% of data in today's world has been created in the last two years,[58] and the volume continues to grow exponentially. Indeed, the challenges faced by each organization at its strategic levels are to be able to manage all this data and to submit it to the processes where it is transformed into knowledge; these challenges are not minor. At this point, technological tools are a major asset. It is also said that the greatest investment concerning technological development to solve this data management problem are coming from the civil sector, giving the defense sector the category of "Secondary Customer Status.”[59] Therefore, utilizing civilian

technology companies to develop and continuously update visualization tools that manage massive amounts of information is exactly what this paper intends to highlight, considering the enormous potential presented today by systems such as VR/AR. These tools could facilitate the task of the strategic leader in the process when that information becomes knowledge, understanding, and wisdom for decision making.

In this case, the recommendation is straightforward. It is necessary to obtain the maximum advantage provided by the civilian industry and its technological advances such as robotics and artificial intelligence to analyze Big Data and then consider the best visualization tool to ensure that strategic leaders can cultivate clear knowledge of the situation when making decisions.

The last factor extracted from the analysis is the *Equipment requirement*, which was initially identified as a strength in the sense of "less equipment required," meaning that having these new visualization technologies may require simpler workspaces with less equipment. The old workstations with multiple screens filling large areas become unnecessary when using systems such as VR/AR/MR where the hardware is getting smaller and smaller. At this point, one can imagine not only the strategic level using these systems but at all levels. A priori and without further analysis, it can be deduced that the costs and the amount of equipment required could be lower which complements the *Adaptability* factor mentioned above.

As in the previous recommendations, it is necessary to start slowly implementing and testing VR/AR/MR at all levels and let the strategic leaders have the possibility to adjust them to their own needs. The idea is, in the future, to be able to measure the effectiveness of incorporating this technology into the strategic decision-making process.

CONCLUSION

The potential use of technologies such as those studied in this research paper is an opportunity within any organization. The degree of incorporation of these technologies varies at multiple levels within this same organization. The identification of the problem related to the low degree of VR/AR integration at the strategic level has led this study to identify some difficulties that are commonly encountered when incorporating innovative ideas at the strategic level. The demographics that generally characterize the senior strategic leader, the notion of mistrust, as well as cybersecurity and information management vulnerabilities, are aspects that were evidenced.

Being able to determine key factors for the incorporation of these technologies at the strategic level and that are useful in the decision-making process, helped to focus the appropriate recommendations that constitute the foundation for future steps in a possible implementation phase.

The preceding concludes that these new technologies, especially AR, deliver superior adaptability in physical domains and augment the ability to scan and make sense of new and changing environments. The superior decision speed capability is enhanced in combination with the presentation of the different scenarios. Moreover, the new trend of multidomain and the necessity to manage multiple OODA loops at the same time allow an organization to foster the potential use of VR/AR. Thus, the management of information, transforming it into knowledge, considering the Big Data available is another reality that boosts innovation and paradigm shift in the equipment that is commonly required in IT.

Finally, the recommendations set out guide how the potential use of VR/AR/MR can be useful and improve the decision-making process within the VUCA/ JIIM environment.

ENDNOTES

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