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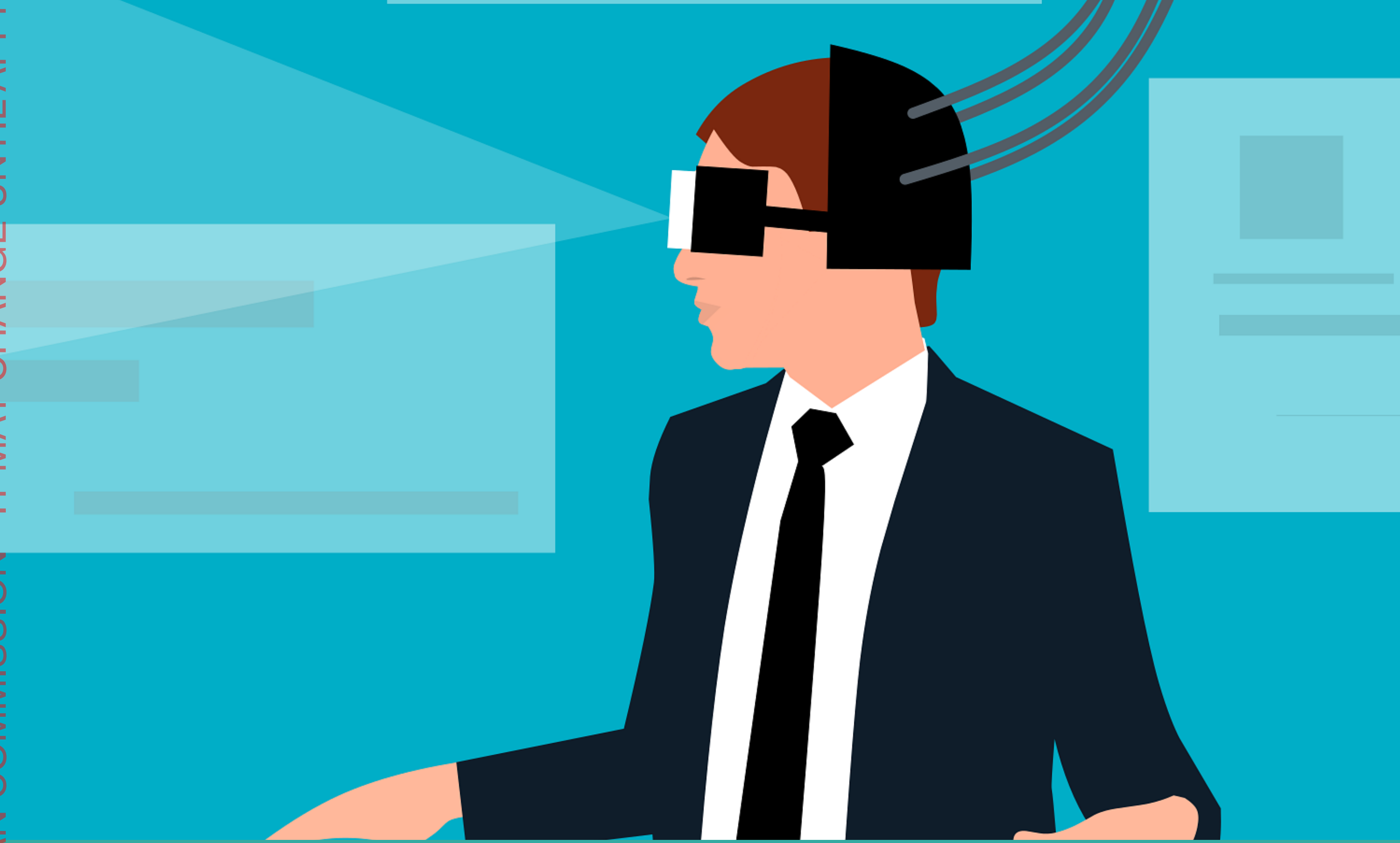

The integration of new technologies (virtual and augmented reality tools) in strategic decision-making processes

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Executive summary

The report explores the integration of Virtual Reality (VR) and Augmented Reality (AR) technologies in enhancing the effectiveness of Strategic Management Tools (SMTs) used in decision-making processes.
While useful to facilitate complex decision making, the application of SMTs has limitations and faces content analysis challenges, procedural complexities, and issues due to psychosocial behavioural dynamics. This report provides a comprehensive analysis of these challenges and offers principles and examples on how to address them through the application of VR and AR technologies.

Key Findings

Strategic Management Tools and their limitations

SMTs are crucial in aiding decision-makers to develop organizational strategies. The report identifies their limitations and proposes methods to address them.

Leveraging VR and AR for Enhancement

The integration of VR and AR technologies in strategic decision making can potentially overcome the limitations of SMTs. These technologies offer immersive experiences that can enhance cognitive processes and decision-making efficacy. The report offers guidance on how to configure these technologies through:

- An empirical analysis of the challenges faced while employing SMTs.
- An 'augmentation configurator' derived from augmented cognition literature, which provides the principles on how to match the challenges in SMTs deployment with the augmentation potential of AR and VR technologies.

Practical Applications and Future Directions

The report not only helps the design of VR and AR augmentations but also provides practical examples showcasing their application in strategic decision making. It serves as a guide for businesses to harness the power of immersive technologies in the implementation of SMTs.

In conclusion, this report advocates for an era where digital tools are seamlessly integrated with organizational processes to augment human capabilities. It offers actionable insights for effective and accessible integration of immersive technologies in strategic decision making.

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Introduction: What is this report about?

Strategic Management Tools (SMTs) have long been recognized as essential support to decision makers in developing organizational strategies. While these tools are powerful enablers, their effectiveness can be limited by issues related to content analysis, procedural complexities, and the psychosocial dynamics during implementation.

This report focuses on how it may be possible to leverage Virtual Reality (VR) and Augmented Reality (AR) to enhance the effectiveness and ease of implementation of SMTs. It provides companies with actionable insights for a more effective and accessible integration of immersive technologies in strategic decision making (DM).

Results are achieved by matching an empirical analysis of challenges encountered whilst employing SMTs with the augmentation potential of AR and VR technologies. This matching process is facilitated through a configurator of augmentations rooted in a systematic review of the VR and AR applications discussed to date by the augmented cognition literature (Figure 1).

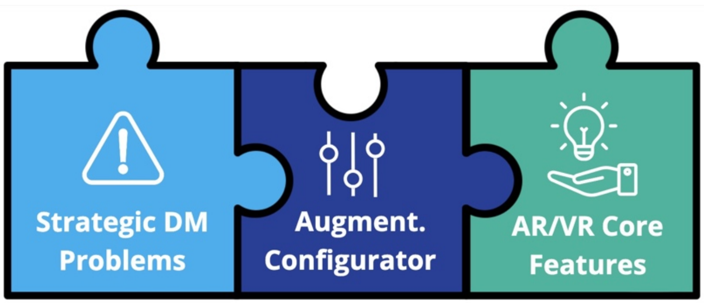

Figure 1. Conceptual scheme of the report: an augmentation configurator is used to match strategic decision-making problems with the potential (core features) of immersive technologies.

The first part of the report delves into an exploration of SMTs and their limitations. We explain the need for tools in strategic decision making (Section 1.1), framing them as decision aids (Section 1.2) and understanding their diffusion and usage (Section 1.3). A fine-grained exploration of the roadmapping tool (Section 1.4) will be used as a lens to uncover and list the challenges that have an impact in the utilization of SMTs in general (Section 1.5).

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The second part of the report proposes augmentation solutions by matching the problems in deploying SMTs with the core features of AR and VR. This entails an introduction to augmented cognition as a discipline which guides tool development (Section 2.1), an exploration of previous applications of AR and VR that culminates in the development of an 'augmentations configurator' (Section 2.2), and an elucidation of the potential offered by AR and VR technologies (Section 2.3). The utilization of the configurator will enable the identification of the STM challenges that can potentially be addressed using immersive technologies (Section 2.4). Practical examples showcasing the integration of these technologies in supporting the cognitive processes during strategic decision making will be shown in Section 2.5. Future research directions will conclude the report (Section 2.6).

> **"This report is a guide to harness the power of AR and VR in strategic planning**

In brief, this report is a guide for organizations seeking to harness the power of immersive technologies in strategic planning, anticipating an era where digital tools are seamlessly integrated into organizational processes that augment human capabilities to take complex decisions.

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Part 1

Strategic Management Tools to augment decision making

Key Insights

- **What is strategic decision making (DM) and why it needs tools**
- **How Strategic Management Tools (SMTs) help taking strategic decisions**
- **Limitations of SMTs and the need for augmentations**

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1.1 The need for help in supporting strategic management decisions

The contemporary industry landscape evolves very quickly and managers are not afforded the luxury of time in taking strategic decisions. Decision making is complex and executives cannot address a limited set of issues in isolation. Instead, they are faced with the need to reconcile risks and rewards, while relying on knowledge coming from various directions simultaneously at a fast pace. Strategic decision making needs to navigate volatile, uncertain, complex, and ambiguous environments (Lawrence, 2013).

Consider, for example, the integration of electric vehicle (EV) technology within the automotive sector. EVs, invented even before combustion engines, remained overshadowed for over a century. By 2010, prior to the launch of iconic EVs, the industry had perfected the manufacturing of traditional combustion engines cars, and the understanding of customer preferences for new models. Although aware of EV opportunities, traditional automotive managers faced significant uncertainty. The technology for EVs was nascent, with many challenges including battery capacity and safety, and the lack of a charging infrastructure. Market interest in EVs was also unclear, complicating investment decisions in new technologies and in initiating infrastructure transition, including that of adapting skillsets and existing manufacturing facilities in which they had invested billions.

> **Executives needs to navigate volatile, uncertain, complex, and ambiguous environments.**

Automotive managers had to balance investments in new technologies, such as EV with alternative technologies such as hydrogen powered engines. For instance, while transitioning from internal combustion engines to electric or alternative fuel designs, they needed to decide whether to develop charging stations or hydrogen distribution networks. Such shifts required new components, often not available from existing suppliers, raising questions about potential new providers. Maintaining competitiveness in current markets

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while staying alert to government policies, consumer trends, and new competitors in the EV space added to the complexity. Analysing these decisions retrospectively reveals varied responses among manufacturers. However, making such decisions in real-time, is a challenging endeavour.

Strategic management as a field has developed a collection of theories and frameworks all directed toward assisting managers in strategic thinking, planning, and decision making. In essence, strategic decision making revolves around ensuring the long-term success of the entire organization and serves as a mechanism for managers to plan for the future (Stonehouse and Pemberton, 2002). The field has overall concurred that breaking the complexity of decisions into manageable components enables managers to discern the connections between disparate pieces of information and to improve the anticipation of the consequences and implications of strategic decisions. It also promotes the examination of each issue from multiple perspectives and ways to synthesize ideas to gain a holistic understanding of the bigger picture.

However, in an increasingly global, interconnected, hyper-competitive, and fast-paced world, managers are expected to embrace an increasingly intricate comprehension of emerging environments (Martin, 2007; Plambeck and Weber, 2009; Raisch *et al.*, 2009). It is evident that the limited capability of humans to rationalize complexity ('bounded rationality', Simon, 1997) is challenged by the raising complexity of the environments matched with the increased availability of information compared to the past. This is why decision-makers and strategy researchers develop and adopt tools, based on the theoretical principles above, to overcome their limits. These tools, supported by theoretical frameworks and validated through years of application, serve to assist managers in understanding the environment and in taking decisions in response. The next section introduces these strategic decision-making tools as cognitive aids for decision makers.

Origins of strategic management

The concept of strategy has its roots deeply embedded in military and political contexts. The term originates from the Greek word "strategos," which translates to "general" (Bracker, 1980).
One of the earliest and most influential works on strategy is Sun Tzu's "The Art of War," a Chinese military treatise dating back to the 5th century BC (Tzu, 2008). This work emphasizes various aspects of warfare strategy, including the importance of deception, flexibility in tactics, and understanding the strengths and weaknesses of both oneself and the enemy.
After World War II there was an increased demand for strategic concepts in business. This need arose as businesses transitioned into an environment that was rapidly evolving and becoming more competitive. Ansoff (1969) identified two key drivers behind this environmental shift:

1) a notable increase in the pace of change within companies,
2) the rapid integration of scientific and technological advancements into management practices.

Throughout its history, strategic management has continuously adapted to the changing business environment, integrating insights from various disciplines, including economics, sociology, and psychology. Its evolution reflects the ongoing challenge of navigating complex and dynamic business landscapes.

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1.2 Strategic Management Tools (SMTs) as decision augmentations

Strategic management as a discipline has provided a large set of practical tools called Strategic Management Tools (SMTs). SMTs should be viewed as means to an end, with their primary purpose being to support and guide the process of managerial decision making (Wright *et al.*, 2012). The rationale for their adoption is grounded in the recognition that “we are not perfect decision-makers, [and] we can do better through more structure and guidance” (Clemen and Reilly, 2013).

These tools have been defined in various ways, such as ‘cognitive aids’, ‘strategy tools’, ‘heuristic devices’, ‘conceptual schemas’, ‘psychological tools’, ‘knowledge artifacts’, or ‘tools for thinking’ (Grant, 2003; Gray, 2007; Gustafsson *et al.*, 2023; Jarzabkowski, 2004; Jarzabkowski and Wilson, 2006; Orndoff, 2002; Pelz, 1978; Stenfors, 2007; Wilson and Jarzabkowski, 2004). Regardless of the terminology, their primary function remains the same: alleviating the burden of decision making by facilitating cognitive steps and providing logical support (Wright *et al.*, 2012).

This report adopts the concrete definition from Keltsch (2011, page 22) which defines an SMT as *“a practically applicable device with the specific purpose of delivering analysis about the company’s position and performance, providing decision support or stimulating decisions and actions”.*

Examples of the most taught SMTs in strategy courses (Kachra and Schnietz, 2008) include:

- **Porter's Five Forces Model**: Analyses industry competitiveness through five forces: new entrants, substitutes, buyer power, supplier power, and rivalry.

- **SWOT Analysis**: Assesses Strengths, Weaknesses, Opportunities, and Threats related to business competition or project planning.

- **McKinsey 7S Framework**: Evaluates organizational effectiveness by examining seven internal elements: strategy, structure, systems, shared values, skills, style, and staff.

- **Balanced Scorecard**: Aligns business activities with the vision and strategy, focusing on financial, customer, internal process, and learning/growth perspectives.

- **Boston Consulting Group (BCG) Matrix**: Categorizes products into Stars, Cash Cows, Question Marks, and Dogs based on market growth and share.

> **An SMT is a practical device to deliver analysis, provide decision support or stimulate decisions and actions.**

The BCG product portfolio matrix, as explained by Gustafsson et al. (2023), is a good example to explain SMTs as a decision tool (see Figure 2, page 16). The BCG matrix provides a visual representation of how products can be categorized based on their market growth and market share. Four distinct positions are outlined which help managers to classify and assess their own product portfolio:

- **Stars** (large market share in a fast-growing market)
  They generate substantial cash flows but also absorb significant amounts of cash due to their rapid growth rate. They are considered the best opportunities for the company's growth and benefits (e.g., Apple's iPhone).
- **Question Mark** (small market share in a high growth market):
  Products which have high demand but low profit due to a low market share. It is not known if they will become a Star or drop into the Dog category (e.g., at the time of writing these could be Tesla's solar panel products; they have a small market share, but the sector is growing and the battle for market-share could unfold in many ways).
- **Cash Cows** (large market share in a mature/slow-growing industry):
  Products which need very little investment but create significant cash for investment in other business units (e.g., Microsoft's Office Suite).
- **Dogs** (weak market shares in low- or no-market growth):
  Products which lack the capacity to generate significant cash. These are frequently abandoned or reduced in size for economization (e.g., 'New Coke' from Coca-Cola in 1985)

The BCG matrix, as a cognitive tool, offers guidance to managers on how to strategically handle each type. It recommends harvesting Cash Cows to support Question Marks, potentially transforming them into Stars, while suggesting the disinvestment of Dogs.

By simplifying corporate strategy into two fundamental metrics, market growth and market share, the tool provides a schema which simplifies and cognitively supports decision making. It encourages managers to temporarily put aside factors beyond market share and growth, facilitating quicker and more cost-effective decisions regarding investments in products or business areas. It helps managers concentrate on the bigger picture of the whole portfolio of investments and hence to balance the risks. Furthermore, by employing metaphors and imagery it helps to exemplify and remember the characteristics of each type of investment.

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Tools such as the BCG matrix are very powerful and have been used in industry and by consultants for many decades, lowering complexity, focusing attention, and helping communication and alignment across various stakeholders. In the next sections we will cover a few of these tools and debate their strengths and limitations.

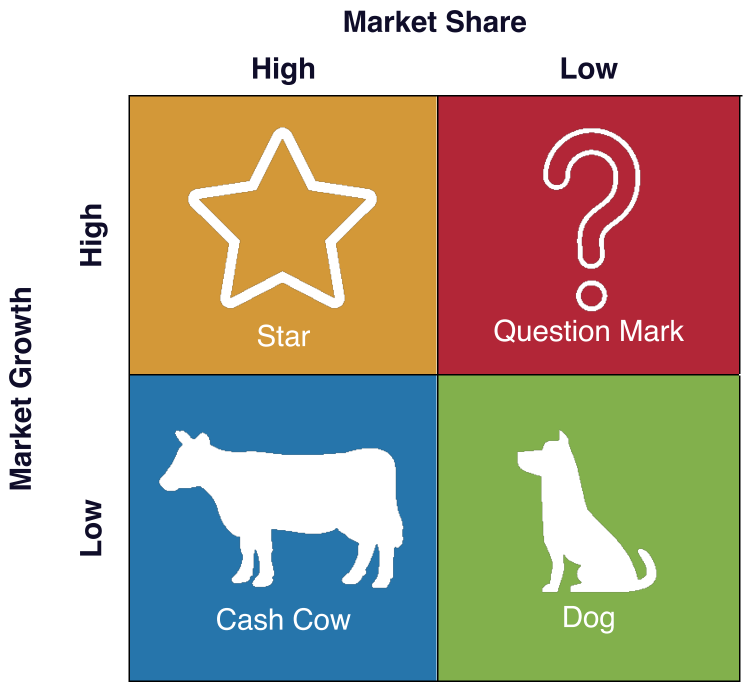

Figure 2. BCG growth-share matrix (Henderson, 1979).

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1.3 Use and diffusion of Strategic Management Tools (SMTs)

As established above, decision-makers use management tools and techniques to address uncertainty in their business and competitive analyses, aiming at more efficient processes, products, and services, ultimately leading to enhanced organizational performance (Davenport *et al.*, 2010; Fleisher and Bensoussan, 2015; Jarzabkowski and Spee, 2009).

The power of STMs has been claimed by researchers and demonstrated by practice. Bingöl et al. (2017) observed that Turkish firms utilizing SMTs report higher performance. Berisha Qehaja et al. (2017) documented a positive correlation between the level of a country's development and the usage of strategic tools and techniques. With reference to the tool of roadmapping (introduced in the next section), Cooper and Edgett (2010) found that best performing firms are about twice as likely to use roadmaps as poor performers.

Management tools perform a variety of functions, often at the same time. These functions can include generating information, providing structure for analysing complex issues, fostering communication and the exchange of ideas among managerial levels, serving symbolic roles, and facilitating formal analysis in the pursuit of objectivity (Frost, 2003).

> **SMTs perform various functions, but cannot replace actual strategy planning.**

According to Clark (1997), SMTs can be integrated into every phase of the strategic management process. Nevertheless, they must be employed in a way that aligns with the unique requirements and business circumstances. While the underlying theory of these "knowledge artifacts" may be often simplified (Jarzabkowski and Wilson, 2006), effectively utilizing these tools demands an understanding of their strengths and weaknesses. Success also depends on the ability to creatively integrate the appropriate tool(s) at the opportune moment and having the right individuals with the requisite skills to tailor the tools to align with the company's goals (Jarratt and Stiles, 2010; Orndoff, 2002; Stenfors, 2007).

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Porter (1996) emphasizes that these tools cannot displace a company's actual strategic planning, as strategies are not crafted by techniques but by the acumen of managers (Hussey, 2007). In other words, SMTs can support specific aspects of the strategic management process but should not be viewed as a substitute for the managerial expertise and experience required (Whittington, 1996).

The variety of tools available for practitioners is considerable and several attempts have been made to categorize planning tools. Prescott & Grant (1988) undertook a study encompassing 21 strategic techniques across 11 dimensions. Likewise, Webster et al. (1989) compiled a list of the 30 most utilized tools for strategic planning. Clark (1997) investigated 66 SMTs, with 33 of them being predominantly employed. Lisiński & Šaruckij (2006) presented 28 strategic tools and categorized them into four primary groups.

Mortara et al. (2014b) identified more recent reviews that classify SMTs based on their diffusion (e.g., Gunn and Williams, 2007), the selection process and reasons behind their adoption (e.g., Popper, 2008) or the nature of tools, aiming to comprehend how they can be perceived, combined, and integrated (e.g., Phaal et al. (2012), concluding that there is a diverse understanding of these tools and their application.

In practice, the array of tools available to executives for deployment is large and has grown massively since the dawn of business strategy in the 1960s (Reeves et al., 2015). A study by Phaal et al. (2006b) identified more than 850 tools only based on the 2×2 matrix format. Considering the multitude of tools proposed by

Combining tools

SMTs can be deployed in many ways for different purposes, and typically need to be customized to context. All tools have strengths and weaknesses, and in general must be combined into a toolkit to address practical problems. According to (Mortara et al. 2014) management tools:

- can be applied to a great number of management decisions (e.g., strategy formulation or strategy implementation).
- are applied to help achieve certain aims (e.g., to compare different options, to quantify, to visualize etc.).
- rely on techniques ranging from people-based qualitative techniques such as workshops, to numerical simulations and modelling.
- can be configured to encompass several aspects related to the business, such as timeline (from past to present, from short & medium- to long-term), internal or external business aspects.
- are implemented in different ways (e.g., they can be used one-off or systematically).

Kerr et al. (2013) proposed a modular approach for coherent development and application of strategic management tools. Based on the principles of 'modular', 'scalable' and 'visual' the toolkit offers a structured example of how different SMTs, typically employed in isolation, can be put together to support a range of management decisions and processes (Phaal *et al.*, 2006a).

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consultants or academics that have not gained widespread adoption, the list gets too extensive to enumerate (Jarzabkowski and Kaplan, 2015).

Despite their vast variety and extensive adoption, these tools do not serve as a silver bullet for strategic decision making. The next section will introduce roadmapping, a widely used management tool, which will be used as a platform to pinpoint and categorize the challenges that persist in decision making despite the application of SMTs. Amongst all these tools, roadmapping has been chosen for its representative power as a tool that can most easily help linking other tools in a toolkit.

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1.4 Roadmapping: a lens on strategy

1.4.1 What is roadmapping?

Roadmapping has emerged as a powerful approach for aiding in the development and implementation of integrated strategy, long-term planning, innovation, and foresight activities (Kerr and Phaal, 2020).

Kerr and Phaal (2022) define a roadmap as *"a structured visual chronology of strategic intent*." Roadmapping is a process that uses a canvas arranged spatially and temporally - the roadmap - to capture, connect, and disseminate information (Kerr *et al.*, 2012a; Phaal *et al.*, 2004b). It acts as a strategic lens to address challenges and opportunities. It is flexible and scalable for various situations, enabling stakeholders to achieve consensus and realize their strategic intent (Kerr and Phaal, 2019, 2022; Phaal *et al.*, 2004b; Phaal and Muller, 2009).

The most common approach, illustrated in Figure 3, involves multiple layers plotted against a timeframe, incorporating both market and technological perspectives, which allow an exploration of market, product, and technology evolution and their linkages (EIRMA, 1997).

Origins of roadmapping

The origin of roadmapping can be traced back to the 1960s in industrial engineering management, with high tech organizations such as NASA, Boeing, and GE using similar approaches (Kerr and Phaal, 2020). Notable contributions to roadmapping were made by companies such as Motorola, BP, Philips, Lucent Technologies, and the Semiconductor Industry Association, raising its profile and demonstrating its effectiveness.

Since then, the practice has spread across industries, regions, and nations, becoming widely used and recognized by companies and government agencies at the highest levels (Kerr and Phaal, 2020). As of now, more than 1100 publications involving roadmapping have been identified (Phaal, 2019) and research on roadmapping has developed a solid body of knowledge with several 'schools of thought' distinguished by different emphasis and perspectives on the practice (Park *et al.*, 2020).

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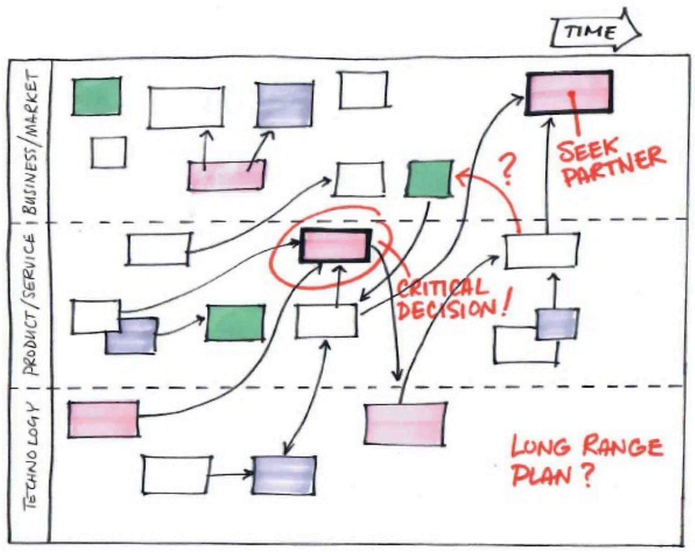

Figure 3. The structured visual format of roadmaps support communication and strategic alignment. Source: Phaal et al. (2010).

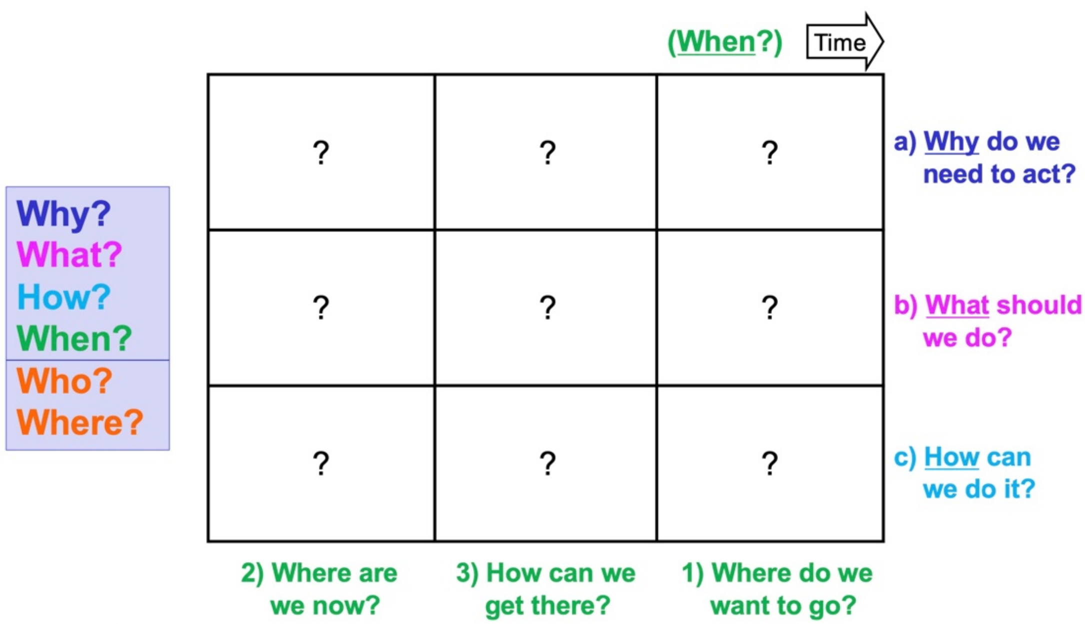

Figure 4. General roadmap framework is structured to address six fundamental questions: Why, What, How, When, Who and Where?

The generic roadmap framework (Figure 4 above) is very flexible and can be adapted to virtually any strategic context, in terms of structure, content and process. It addresses fundamental questions that apply to any strategic context. The roadmap serves as a knowledge integrator to combine different tools and approaches, and provides the big picture at key decision points, such as strategy milestones and product development stage gates.

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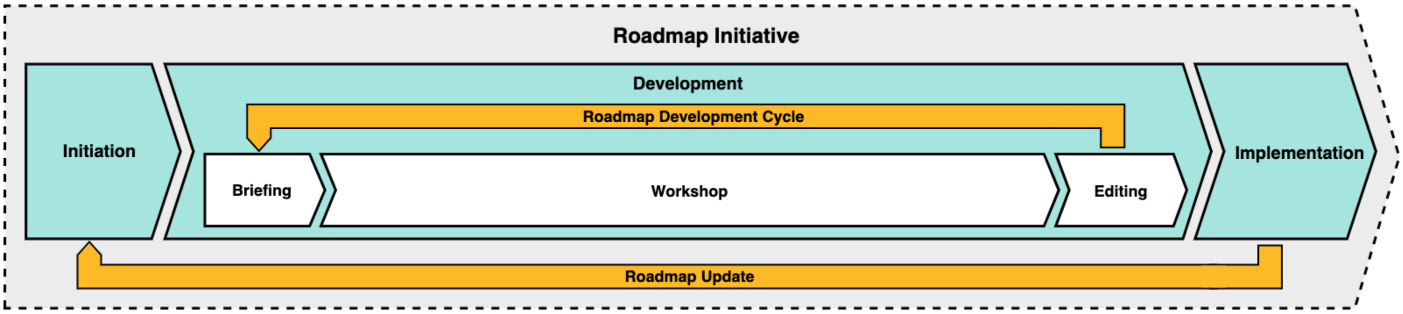

Figure 5. The typical timeline of a roadmapping initiative, adapted from Gerdsri et al. (2013)*.*

The typical timeline of a roadmapping initiative (Figure 5) comprises of an initiation stage (which focuses on preparing the organization before commencing the roadmapping process), a development stage (aiming to create a desired roadmap by collecting essential information and involving the right individuals), and an integration stage (which seeks to incorporate the roadmapping outcomes into ongoing business planning activities, enabling continuous review and timely updates of the roadmap) (Gerdsri *et al.*, 2009). The development phase comprises an iterative process, during which focus and detail increase with each iteration (Gerdsri *et al.*, 2009; Vatananan and Gerdsri, 2013a). Typically, in the preparatory phase, required information on the context and application of the roadmapping exercise is gathered, material is prepared (e.g., configured and pre-populated canvasses) and attendants are briefed. A deployment process (typically a series of workshops, as captured in Figure 6) guides participants in populating the roadmapping template. After deployment, an editing phase will concentrate on polishing and consolidating as well as disseminating the resulted roadmap to key stakeholders. Finally, the polished roadmap is implemented in the company and plans for updates are made (e.g., roadmap may be updated once a year for budgeting, or in line with product development milestones).

Figure 6. Typical roadmapping workshop: a workshop-based approach to implement SMTs empowers collective participation, fostering a dynamic environment where users can actively engage and collaborate. Central to this method is the role of the facilitator, who neutrally guides the group through various tasks and interactions, including those with the SMT. This facilitation is key to enhancing group efficacy, enabling participants to more effectively tackle and resolve issues together (Kerr et al.*, 2013). Image source: Cambridge Roadmapping.*

1.4.2 Roadmapping as a lens on strategy

This report uses roadmapping as a representative tool to uncover and study the challenges in decision making while using SMTs. Several compelling reasons are behind this choice.

Management tools typically focus on parts of the system (Mortara et al., 2014b), providing more granularity and analytical power. However, tools may oversimplify or miss out on dimensions. For instance, the already mentioned BCG matrix (Henderson, 1979) helps categorizing strengths and weaknesses of products portfolios against market trends, but lacks a temporal analytical perspective (Mohajan, 2017). Scenario planning, which focuses on exploring and fleshing out visions of future potential scenarios (Porter, 1985), overlooks contemporary issues and factors.

Roadmapping has a distinctive role as an integrator of other STM tools. It is the only tool that is designed to provide a holistic view of most aspects concerning the complex systems surrounding a decision, including internal and external, demand- and supply-side drivers. Roadmapping allows the connection between these aspects to be viewed over time. The roadmap can be considered the 'picture on the jigsaw box', which helps to understand how the various pieces of the strategic puzzle fit together. It therefore supports alignment, integration, and synchronization of many tools.

> “ **Roadmapping is a prime integrator and offers a holistic view on most aspects concerning strategy.**

Moreover, roadmapping exhibits a remarkable degree of flexibility, making it suitable for a wide range of decision-making contexts and circumstances (Phaal and Muller, 2009). The adaptable nature of roadmapping accommodates a broad spectrum of scales and complexities within the system (Phaal *et al.*, 2004a). It offers tailored guidance for stakeholders ranging from government policymakers to corporate strategists and individual decision-makers. Its widespread adoption across such diverse fields not only indicates its effectiveness, but also presents ample opportunities for research and observations, making it a valuable lens for the aim of this study.

This chapter introduced roadmapping as an integrative tool, discussing its adoption as a lens for examining persistent challenges in decision making despite the use of SMTs. The final section of Part 1 will identify and delve into some of these challenges, with a particular focus on those deriving from cognitive biases and limitations.

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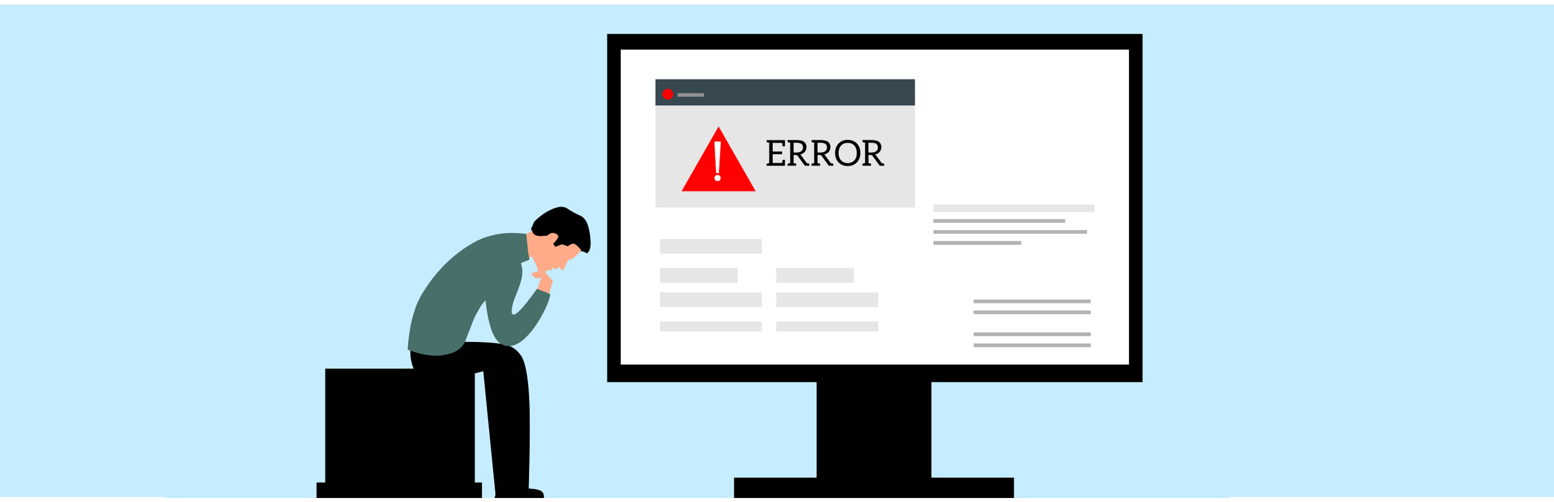

1.5 Strategic Management Tools (STMs) have limitations

While the chances of success appear considerably higher for those who do use SMTs, adopting a particular management tool or framework does not guarantee success. The deployment of SMTs requires a complex set of skills and processes which support positive human interaction. Adopting a tool does not result in a challenge-free decision making. For instance, studies on roadmapping remark on the complexity of the process (Phaal *et al.*, 2004b), or the cognitive and psychological impediments faced (Kerr et al., 2012c). This section will identify a list of challenges in the implementation of SMTs, some of which can be potentially addressed using Augmented and Virtual Reality as will be exemplified in Part 2 of the report (Figure 7).

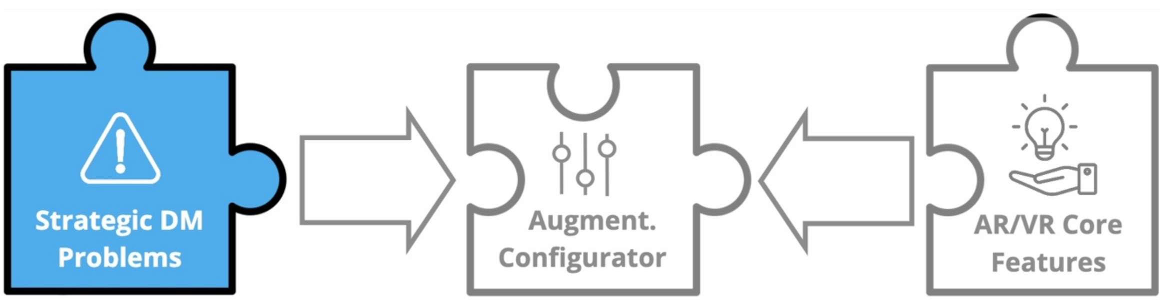

Figure 7. This section identifies the list of problems in strategic decision making that will be addressed using AR or VR.

To clarify the challenges that still affect decision making despite the uses of STMs, which to date have not yet been completely clarified (Letaba et al., 2015), this report used a two-pronged approach to categorize the issues: a literature review complemented by interviews with practitioners with high expertise in roadmapping facilitation and use.

The strategic challenges found have been categorized into thematic groups. These groups provide a more holistic perspective on the issues and facilitate a higher-level discussion regarding the nature and dynamics of these problems. A detailed description of the specific challenges is available in Table 1 (see page 28). Although the list might not be exhaustive, considering the dual nature and quality of the sources (literature and experts' interviews), the table is likely to cover the most relevant challenges.

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Methodological approach to identify challenges

Literature review:

The focus was on articles that used the term 'challenges' or synonyms (e.g., 'problems', 'issues', 'obstacles', 'limits', 'pitfalls', 'difficulties') in the context of roadmapping.
Several reviews and bibliometric analysis on roadmapping have been published with different foci on definitions, benefits of the tool, pain points, best practices, and case studies (examples include: de Alcantara and Martens, 2019; Carvalho et al., 2013; Gerdsri et al., 2013; Kerr et al., 2012c; Letaba et al., 2015; Münch et al., 2019; Oliveira et al., 2019; Vatananan and Gerdsri, 2013b).

Among all these contributions, there is a trade-off between exhaustiveness (incomplete coverage of known issues), structure (discussing challenges as a loose list), and level of analysis (insufficient exploration of issues' nature and connections). Furthermore, the COVID-19 pandemic forced organizations to explore remote digital approaches to implement tools, which present new challenges that must now be acknowledged. Hence papers which discussed hybrid solutions for deploying roadmapping (integrating both remote and in-person) were also included (Oliveira *et al.*, 2022).

Interviews:

Seventeen roadmapping facilitator specialists, including employees from multinational tech companies, academics, and professional consultants, were interviewed. Adopting an inductive categorization process (Mayring, 2000), emerging themes and patterns from the interviews were analysed and iteratively refined through a feedback loop with the literature.

The combined result is a structured framework grouping categories of challenges into thematic clusters, which provide a holistic perspective on the issues and facilitate a higher-level discussion regarding the nature and dynamics of these problems.

Categorized by type, problems fall into four groups:

1. **Content-related challenges**:
   These encompass a wide range of issues related to the design of the content of the roadmap. Challenges may arise from uncertainties about what to include in the roadmap before deployment. Customizing the roadmap template (which extends to tool development) include: determining the appropriate amount and type of information to add, how to address higher-level aspects (the company's vision, the decision on the content needed, the assessment of input quality, evaluation of input (e.g., defining KPIs), and the potential effects of the content on participants (e.g., information overload)). Challenges in managing the data collected during and after tool deployment also featured: for example, how to navigate content complexity or how to safeguard against important losses of content or sensitive information leaks, content evaluation after the tool has been deployed, for instance in the evaluation of the quality of the resulting roadmap and how to use it in guiding future practice.

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2. **Process related challenges**[1]:
   The process is central to driving the activity and ensuring outcomes. Kerr et al. (2013) recommend a workshop-based process to deploy SMTs in general, as it encourages group interaction through structured activities to solve strategic problems. In the case of roadmapping, the adaptability of the process makes it applicable to virtually any context, although this introduces challenges such as customizing the process to meet specific needs and environments. During these workshops facilitators bear significant responsibility in ensuring smooth and successful processes, which translates into a facilitation load. Participants may require several iterations to fully understand and embrace the process, and there is a risk of abandoning roadmapping or overlooking the outcome of the process (i.e., the roadmap itself), even after having embraced it. In-person workshops pose challenges related to expense (i.e., resource availability) and difficulties in maintaining a consistent attendance (i.e., attendance quality and quantity).

3. **Psychosocial behaviour-related challenges**:
   The practice of roadmapping involves numerous and complex underlying cognitive factors and social interactions. Individual biases are known to affect decision making. Participants that take part in roadmapping can be distant from the topic discussed (i.e., psychological distance) or attached to preconceived ideas (i.e., anchoring), which could in turn affect reasoning, commitment, and ultimately decisions. Social dynamics within the collective exercise may lead to insufficient participation due to fear of judgment or attempts to monopolise the process (i.e., disruptive behaviour). Trust, whether in people or the process, is another psychosocial factor influencing or influenced by these phenomena.

4. **Tool-related challenges**:
   As roadmapping serves as an augmentation for strategic decision making, the tools used to implement it are not without limitations. Deployment methods involving paper and pen on one side foster discussion among participants, but may create accessibility challenges (e.g., poor readability of contributions). Remote and digital implementation approaches, accelerated by the pandemic, overcome some of those limitations but present adoption barriers.

This categorization of challenges allows a higher-level perspective on the nature of the problems, which helps to identify potential measures to address them. Content-related challenges may require modulation in participants' contribution modalities: for instance, tighter criteria of input content might enhance comparability and standardization, whilst more loose, unregulated content requirements might enhance volume and variability of contributions. Process-related challenges may necessitate adjustments to the process, requiring more emphasis on the phases where those challenges typically appear. Psychosocial behaviour-related challenges demand special attention from facilitators, who, as managers of the process, must find ways to minimize subjectivities and biases, and to social engineer a fair exchange between participants which

[1] While collaborative workshops are a prevalent method for implementing roadmapping in large and complex organizations, they are not the sole approach. For instance, individual roadmapping can be used as a tool for individuals to crystallize their personal visions and strategies (Phaal *et al.*, 2005).

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satisfactorily covers the main issues. Finally, considering factors like available resources, expertise, and digital literacy can guide in the choice of tools.

> **The identified challenges can be extended to other SMTs, as they share common requirements and implementation processes.**

Unsurprisingly, most of the challenges have been identified during the deployment phase, particularly when this is done via workshops. Workshops bring key stakeholders and domain experts together to capture, share, and structure knowledge related to an organization's strategic issues (Phaal *et al.*, 2007). They are complex psychosocial phenomena and involve underlying cognitive and social processes (Kerr *et al.*, 2012b).

The challenges identified for roadmapping can be extended to the adoption and utilization of SMTs in general. These tools, while varying individually, often share common requirements such as the need for specific content inputs and adherence to a structured implementation process. Additionally, they are typically designed for collective rather than individual use, making them prone to psychosocial behavioural dynamics. Furthermore, their effective utilization frequently depends on some form of digital or physical infrastructure or support system.

The extensive range of challenges identified in the use of SMTs not only underscores existing issues but also reveals numerous opportunities for improving decision-makers' outcomes. The second part of the report will present a comprehensive guide for organizations on integrating Augmented and Virtual Reality into strategic decision-making processes. By leveraging the core features of the technology, the guide aims to address and mitigate some of the key challenges associated with the use of SMTs, offering innovative solutions to streamline and enrich the strategic planning experience.

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Table 1. Glossary of strategic challenges during roadmapping implementation.

CHALLENGE CATEGORIES			DESCRIPTION
CONTENT RELATED	Data Management	**Clustering**	Difficulty from facilitators and participants to sort elements on the chart in meaningful and coherent groups.
		Data Security	Risk of leak of sensitive information within or outside the company, along with the potential discomfort of participants in sharing information.
		Knowledge Loss	Valuable contributions are either not captured or discarded.
		Making Connections	Difficulty in linking, graphically and mentally, inputs present in the roadmap to build a narrative, answer questions, understand priorities, etc.
		Prioritization	Difficulty in establishing clear priorities and/or which aspects should take precedence.
	Defining KPIs		Difficulty in defining the right metrics that most reflect progress and success.
	Info Overload		Large volume of data and information that surpasses participants' cognitive capacity to effectively process and manage it.
	Input Quality		Insufficient quality of data to initiate the roadmapping process or inadequate contributions provided by participants during workshops.
		Low Creativity	Difficulty in thinking in a bold, unconstrained manner, avoiding linear and incremental contributions.
		Granularity Level	Insufficient or excessive level of detail of the inputs given the scope of the initiative and the timeframe considered.
		Lack of Analysis	Missing depth of analysis and insights from the available data.
		Lack of Knowledge	Missing of required information to inform the participants and sustain the process.
		Unclear Scope	Difficulty in defining or understanding the purpose, nature, and extent of the required analysis, or the issues to be tackled.
	Template Customization		Difficult or inadequate adaptation of the SMT framework to the various sites, individuals, groups, and purposes it is intended to serve.
	Roadmap Evaluation		Difficulty in assessing the quality of the completed roadmap.
	Uncertainty Management		Difficulty in or lack of acknowledging, analysing, and addressing the inherent uncertainties and risks associated with predicting and planning.
	Vision	**Definition**	Short-term, bounded thinking as well as objective difficulties in defining a favourable future state.
		Alignment to Vision	Scepticism, misunderstanding or lack of commitment related to the vision from key stakeholders.
PROCESS-RELATED	**Facilitation Load**		Complexity of facilitating workshops, maintaining focus, customization, and neutrality while balancing structure and flexibility.
	Process Customization		Lack or difficulty in tailoring the roadmapping process to the company's specific needs and business context.
	Process Understanding		Lack of clarity on how roadmapping works, why it is required and what is expected from the participants or from the process.
	Roadmap(ping) Neglect		Abandonment of a completed roadmap which gets filed and ignored. Inability to establish a self-sustaining roadmapping process.
	Voting		Difficulties in guaranteeing a genuine, fair, and objective voting from participants.
	Workshop-Related	**Attendance Quality**	Missing or inadequate profiles, skills, and expertise present during roadmapping workshops. Inconsistent attendance.
		Equipment Disruption	Workshop material gets lost, damaged, or becomes unusable for the workshop.
		Resources Availability	Lack of resources to create and maintain a roadmap given the resource-intensive nature of workshops.
		Travel Risks	Risks related to travelling for in-person workshops.

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(continued)

CHALLENGE CATEGORIES			DESCRIPTION
PSYCHOSOCIAL	Biases	**Anchoring**	Participants getting attached to their own preconceived believes, ideas or impressions.
		Psychological Distance	(Un)Perceived separation or distinction between an individual and a particular person, object, event, concept, or situation in terms of relevance, familiarity, or emotional connection.
		(Other) Individual Biases	Influence of unspecified cognitive biases that lead to suboptimal or skewed outcomes (e.g., personal preferences of facilitators during the roadmap template design).
	Disruptive Behaviour		Misconduct of participants that jeopardize the workshop.
	Limited Participation		Participants do not engage or contribute to the process.
	Social Influence		Participants get influenced by the presence of peers or senior managers.
	Trust		Participants do not trust the roadmapping process as valuable or reliable.
TOOL-RELATED	**Accessibility**		Difficulties for the participants to access the workshop, it's phases or elements. For example: portions of the roadmap visually blocked by other participants or contributions of poor readability.
	Digital Learning Curve		Difficulties from participants in learning and using software or other digital tools applied to roadmapping.
	Lack of Digitization		Difficulty in implementing (or the absence of) digital solutions to enhance data capture, management, and roadmap updates.
	Tele-meetings		Difficulty in facilitating hybrid or remote meetings.

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Part 2

Augmenting strategic decision making with Augmented and Virtual Reality

Key Insights

- **Augmented Cognition: How digital tools can augment decision making**
- **How digital tools have been used to augment human cognition**
- **Core features of Augmented Reality (AR) and Virtual Reality (VR)**
- **Which strategic problems AR and VR can address**

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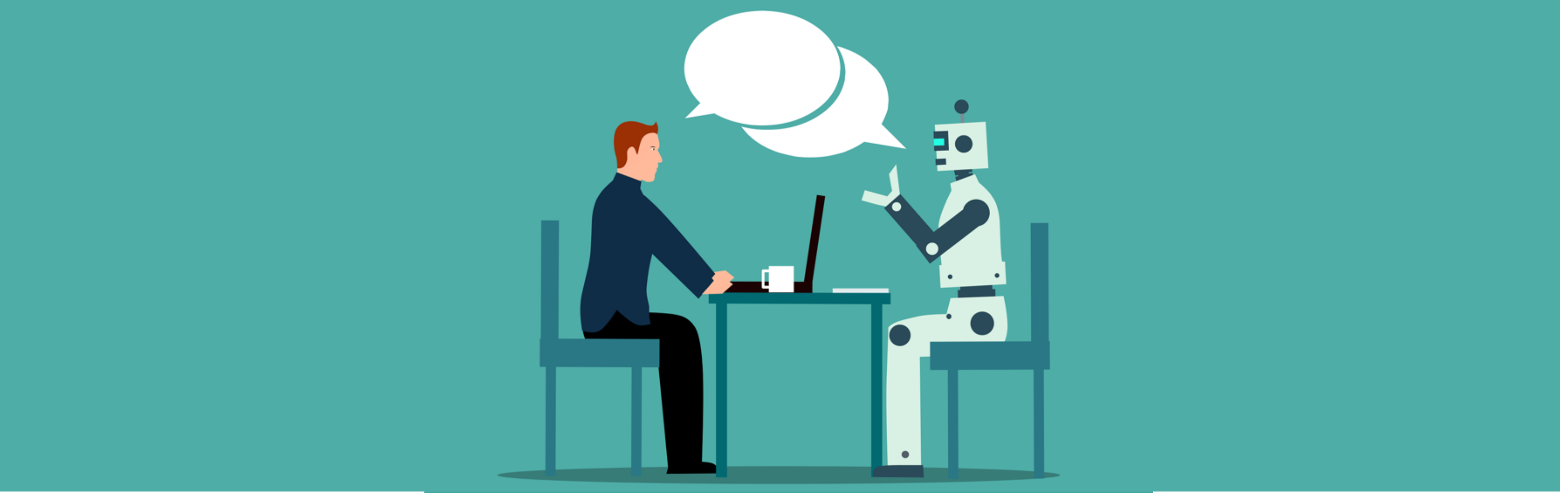

2.1 Augmented cognition: digital tools to augment decision making

Planning, with or without SMTs, relies heavily on cognitive functions. The field of cognitive research in strategic management has significantly contributed to the practice by developing tools that help executives overcome cognitive biases and limitations in strategic decision making (Narayanan *et al.*, 2011). As shown above with the example of roadmapping, the tools do not completely eliminate difficulties in decision making. Each approach has its advantages and shortcomings, and offers a unique perspective for understanding, analysing, deciding, and acting (Phaal *et al.*, 2012). Challenges exist also as a result of the deployment of tools themselves. A combination of tools is likely to be the most effective in supporting managers to address strategic challenges. Digital tools such as Virtual Reality (VR) and Augmented Reality (AR) are well positioned to mitigate some of these problems.

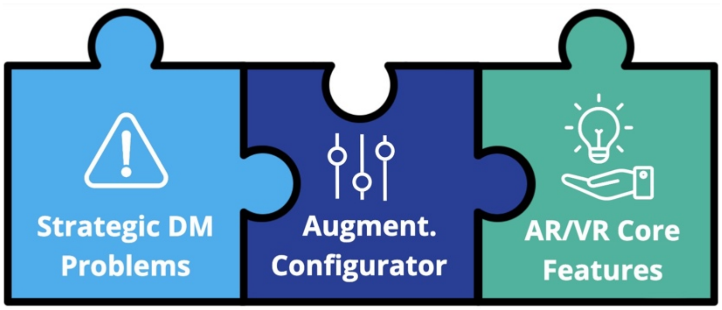

Figure 8. The second part of the report implements a configurator of augmentations from the AC field to match the problems in strategic decision making with the potential of AR and VR technologies.

In fact, the field of Augmented Cognition (AC) focuses on coupling human decision processes and digital tools to enhance human cognitive capabilities. This includes enhancing information processing capabilities (Reeves et al., 2007; Stanney and Hale, 2011), but also mitigating cognitive bottlenecks and biases (Reeves et al., 2007). This is obtained by developing configurations of tools which support humans in their tasks. Examples of cognitive augmentations are GPS navigation tools and digital reminders.

This second part of the report builds on a configurator of augmentations (Figure 8), taken from the AC field to configure AR and VR in strategic decision making to alleviate the existing challenges (Felicini and Mortara 2023a). The next section introduces this configurator to align cognitive challenges with appropriate tools.

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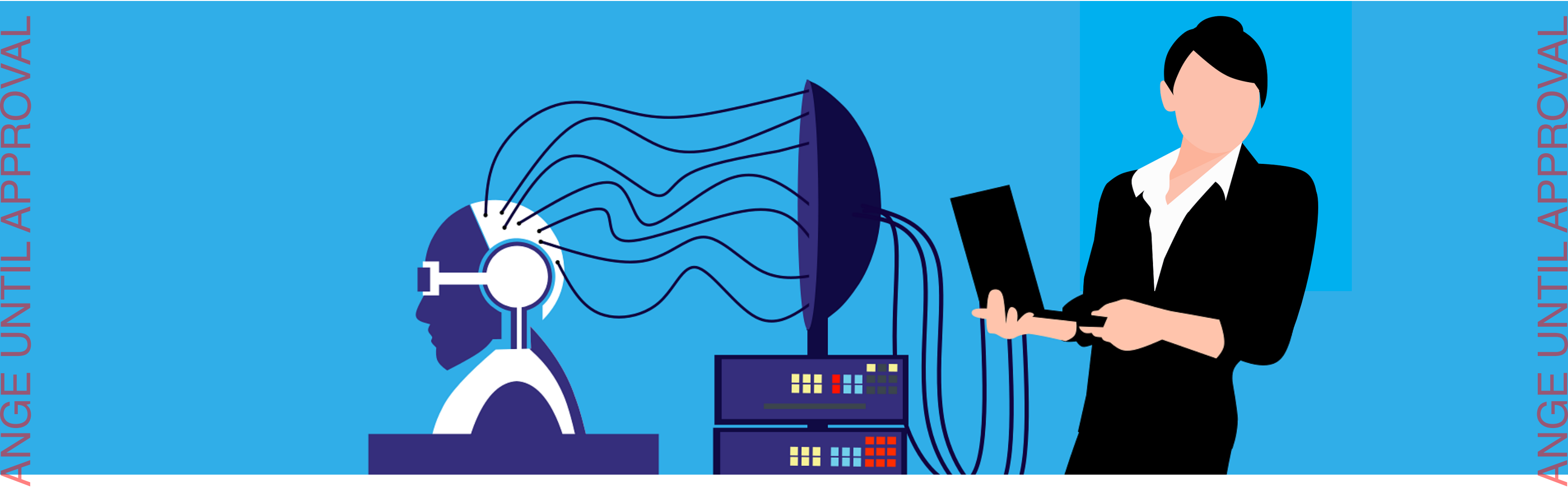

2.2 Exploring previous applications through a configurator of augmentations

The field of Augmented Cognition (AC) studies the application of digital technology to address limitations of human cognition. Its literature presents many examples of augmentations delivered via the implementation of digital tools. This knowledge has been summarized in a configurator (Felicini and Mortara 2023a), introduced in this section, that will be used to match the problems in strategic management with the potential of immersive technology (Figure 9).

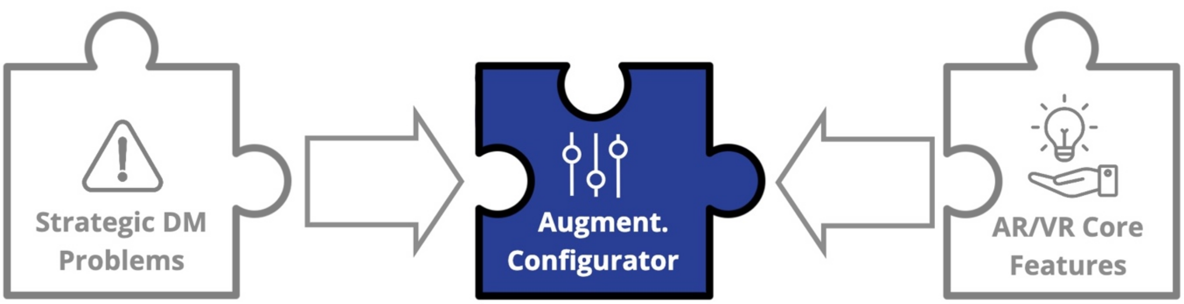

Figure 9. This section introduces an augmentation configurator that is used to match the strategic decision-making problems with the potential (core features) of AR and VR technologies.

The AC field was reviewed and mapped previous applications of cognitive augmentations. For each encountered application they distinguished:

- the field of application (**Field**),
- what the issue was (**Limitation**),
- what the aid provided was (**Augmentation**),
- and how the aid was provided (**Implementation**).

The distinction of these augmentation characteristics separates the augmentation (i.e., the aid given) from the technology adopted to deliver the augmentation (e.g., VR, AR, etc.) and allows to think about tools in an objective, systematic way that is technology-agnostic and focused on the advantages provided to the users. Table 2 at the end of the section shows some examples of how previous AC applications have been classified.

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Felicini and Mortara (2023a) summarized this knowledge in a configurator that can be used to direct the selection of cognitive augmentations tailored to specific problems. Represented in Figure 10, the configurator has four quadrants, each corresponding to a linking grid which correlates two augmentation dimensions as found in the literature. The image exemplifies how, by consulting the linking grids in the configurator, users can efficiently identify which augmentations have previously been employed to solve specific problems and understand which methods have been used for their implementation.

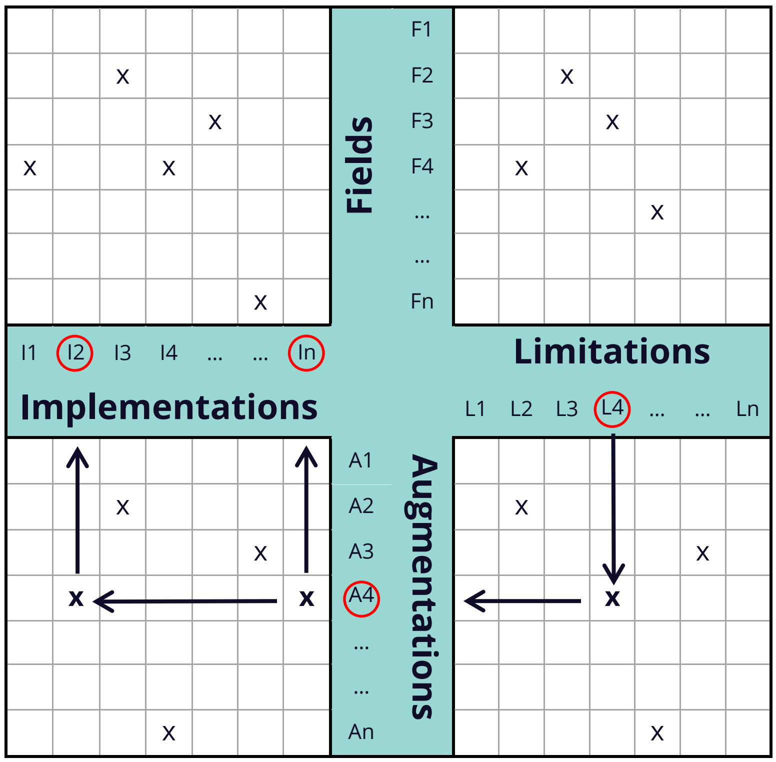

Figure 10. Representation of the augmentation configurator, adapted from Felicini and Mortara (2023a). *Each 'x' in the linking grids indicates that at least one application involving the respective characteristics was found in the literature. The example shows how for a specific limitation (L4) it is possible to find the augmentations that have been tested (A4) and the implementation strategies adopted to deliver it (I2 and In).*

Two of the 4 linking grids (Augmentation-Implementation and Augmentation-Limitations) of the configurator have been included in the appendix (Table 7 and Table 8, pages 63-64). Since this report specifically concentrates on the strategic decision-making field, the other two grids of the configurator related to the Field dimension have been omitted.

Moreover, the augmentation configurator has been integrated with the following additions:

- The limitations categories have been expanded to include biases and heuristics, as frequently identified during literature research and interviews. This additional category (named 'Bias') identifies the mental shortcuts and errors that can influence judgment and decision making, leading to systematic deviations from logic (Kahnemann *et al.*, 1982), and which have a prevalent role in the process of strategic management (Acciarini *et al.*, 2021).

- Each ‘X’ in the grids is here associated through a number with a relevant example from the original study’s database (Felicini and Mortara, 2023b)[2]. This enables readers to directly access real examples related to any combination reported in the study.
- Hypothetical examples have been included to cover some of the white spaces in the original grids, which represent gaps in the AC field (listed in the appendix, Table 10 page 67).

The next section will clarify the potential of AR and VR, which will be leveraged through the configurator to address the strategic management challenges.

SMTs are cognitive augmentations

The characteristics of augmentation apply to SMTs as well. Each strategic management tool can be 'disassembled' into its essential characteristics of augmentation (Mortara et al., 2014b), allowing for a discussion on the aid they provide: what is the problem, what augmentations does the SMT provide, and how it provides them.

Going back to the earlier example of the BCG matrix discussed in section 1.2: in dealing with the complexity of corporate strategy (limitation), the BCG matrix simplifies this complexity (and hence it provides an augmentation) by encouraging users to temporarily set aside considerations of additional information (implementation), focusing solely on market share and market growth.

[2] The online database is an interactive platform for consulting the configurator and accessing the analysed AC literature. Accessible at: https://nicolafelicini.wixsite.com/cognitive-compass

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Table 2. Examples of how the augmentation characteristics have been classified from the cases in selected academic papers in the Augmented Cognition field (see Felicini and Mortara, 2023a).

Publication	**Augmentation Characteristics**			
	Field	**Limitation**	**Augmentation**	**Implementation**
(Dorneich *et al.*, 2005)	*"[...] system to support [...] dismounted soldiers."* **(Military)**	*"This was to avoid disorientation and lack of context [...]."* **(Incorrect focus)**	*"[...] drawing attention to higher priority items [...]."* **(Attentional deployment)**	*"[...] with the additional alerting tones [...]."* **(Audio cues)**
(Dorneich *et al.*, 2005)	*"[...] system to support [...] dismounted soldiers."* **(Military)**	*"[...] performance on these tasks deteriorates considerably over time".* **(Variable performance)**	*"[...] target identification agent provides assistance in locating potential targets [...]."* **(Task load distribution)**	*"Automated systems trained to detect target [...]."* **(Automation)**
(Vadiraja *et al.*, 2021)	*"[...] a technique to assist a reader."* **(Reading)**	*"[...] if the reader is underconfident in some topics [...]."* **(Low engagement)**	*"[...] providing summaries about unclear descriptions [...]."* **(Knowledge provision)**	*"[...]text summary augmentation system [...]."* **(Analytics)**

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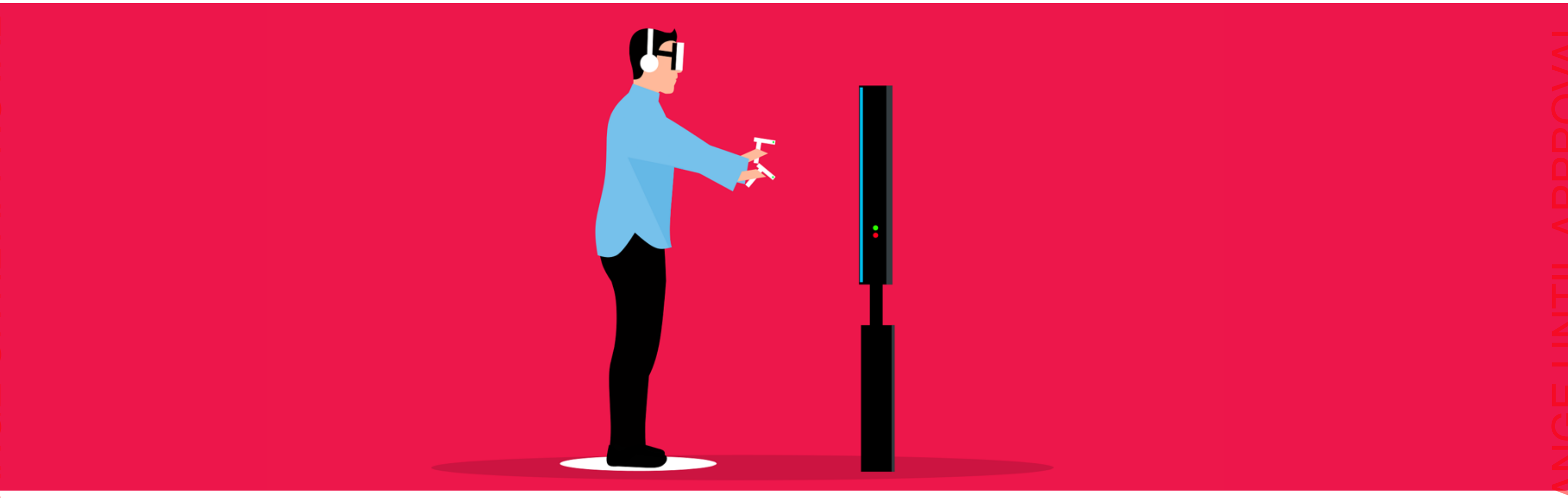

2.3 Core features of Augmented and Virtual Reality

The objective of this section is to articulate the distinctive potential of Augmented and Virtual Reality technologies (Figure 11) to provide augmentations. Specifically, it aims to elucidate the unique features and advantages of AR and VR that warrant their adoption in organizational decision-making processes, allowing a comparative perspective against other prevalent digital technologies. To do that, we rely on the concepts of ‘core features’ of a technology (DeSanctis and Poole, 1994).

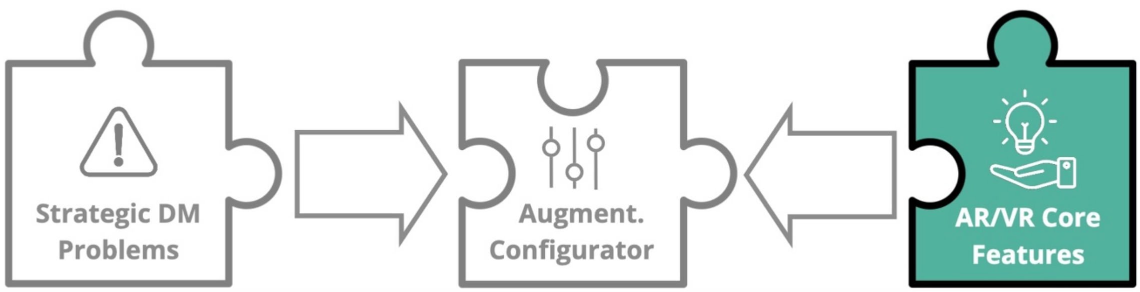

Figure 11. This section clarifies the unique potential (core functionalities) of AR and VR.

Core features are essential capabilities that define a technology's basic identity. As exemplified by Markus and Silver (2008), in an electric washing machine, core features include mechanisms for automatic water intake, agitation, and rapid spinning of clothes. These are fundamental to the machine's operation and distinguish it from manual washing methods. In contrast, optional features like selecting the duration of the wash cycle, adjustable legs, and compartments for bleach are not essential but add extra functionality. Core features like clothes spinning contribute directly to the benefits of using a washing machine, hence define the technology identity. Optional features such as bleach dispensers are not as crucial to its primary function.

After comparing Augmented Reality and Virtual Reality with other digital technologies and exploring their respective capabilities, we identified three core features of AR and VR: **Immersivity**, **Interactivity and Situated visualization** (AR only). These core features are summarized in Table 3 (page 39) and described hereafter.

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Features vs Affordances

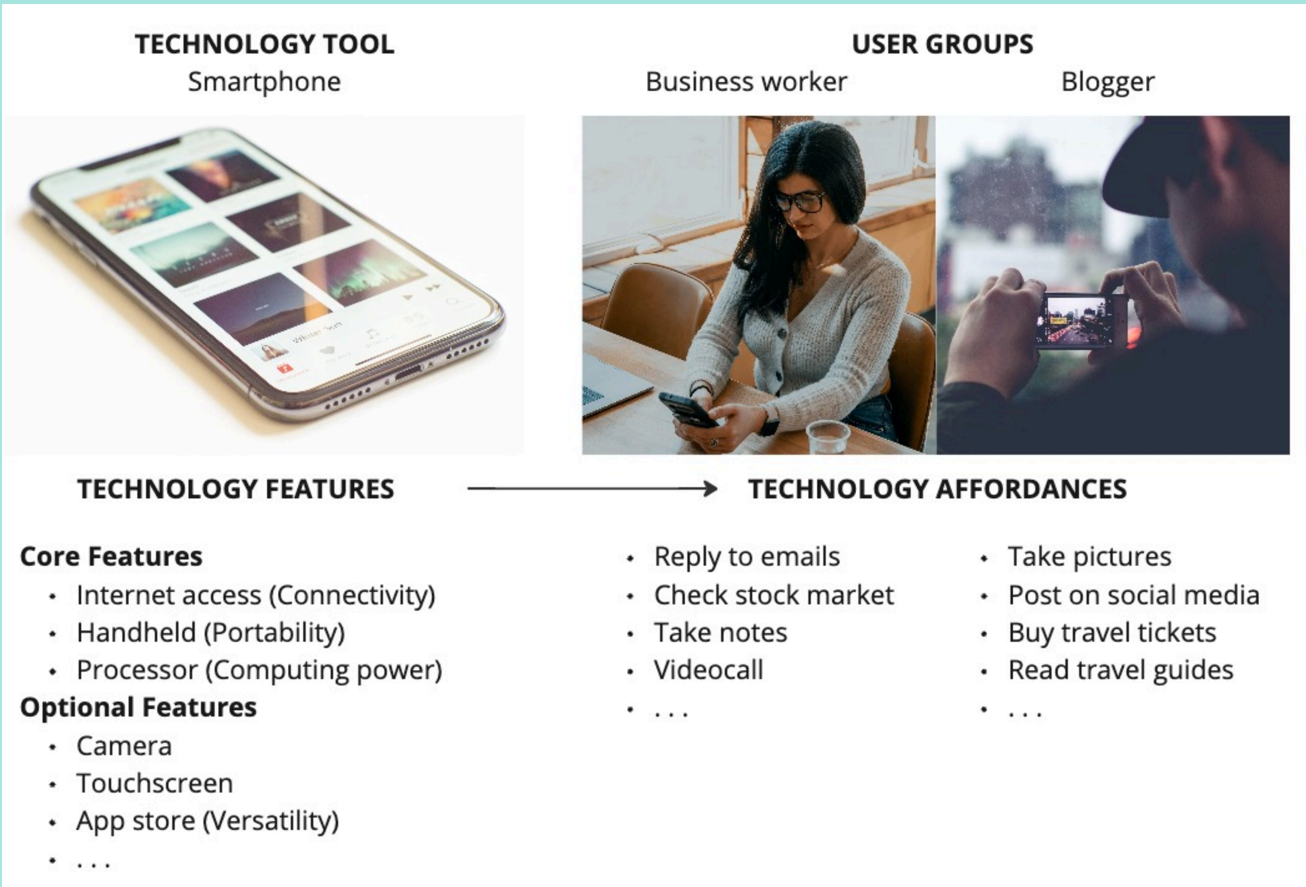

Figure 12. Relation between functionalities and affordances of smartphone technology.
Images sources (left to right): Hilthart Pedersen, Clay Banks and Charlotte Butcher on Unsplash.

It is crucial to understand the distinction between features and affordances of a technology. Features are the inherent capabilities that identify a technology, determining what it can do. Affordances, however, go a step further. They are defined as the possibilities of action that a technology can offer to users, given their goals (Markus and Silver, 2008). This means that the same technology, with its fixed set of features, can provide different affordances to different users, depending on their unique goals and how they interact with the technology. Essentially, while features are static attributes of the technology, affordances are relational and user specific (see Figure 12 and Figure 13 for examples).

AR and VR technologies are frequently discussed in terms of their affordances – for instance, how they enable more intuitive remote collaboration through avatars or provide a secure training environment for military personnel. However, focusing on affordances obscures the fundamental capabilities of the technologies and complicates the comparison with other technological solutions. This report relies on the concept of core features to better define the unique potential of immersive technologies and justify their potential integration with SMTs.

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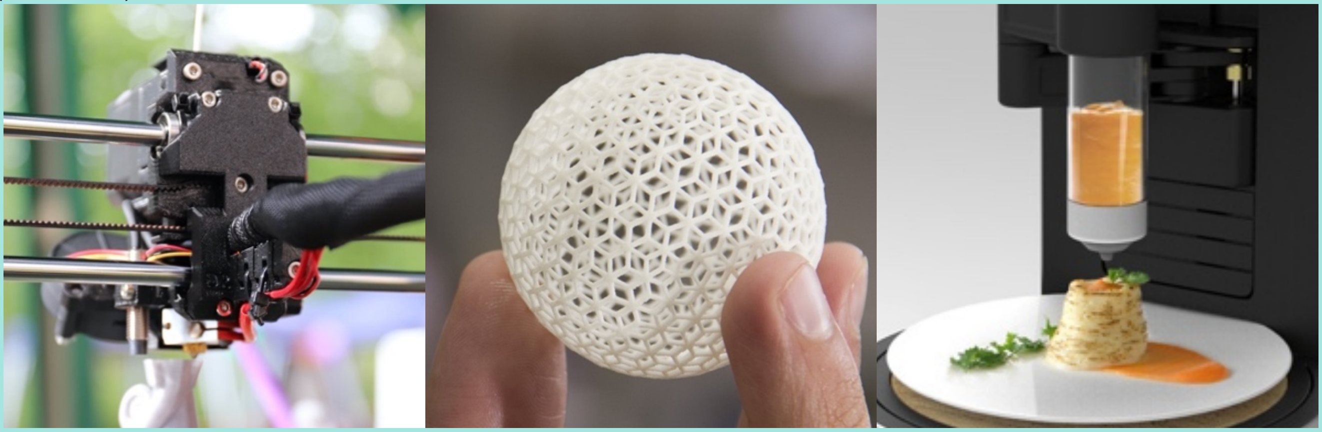

Figure 13. As exemplified by Mortara and Flammini (2018)*, two core features of 3D printing (left image) include (1) the precise deposition of a range of materials (2) in designated locations. These features afford designers to make intricate structures using composite materials (central image). Additionally, looking towards the future, this technology holds the potential to afford the on-the-spot creation of complex dishes (right image).*
Images sources (left to right): Lucie Siegelsteinová on Unslash, metalurgiamontemar0 on Pixabay, Creative Machines Lab, Columbia University.

2.3.1 Immersivity

A core feature of both Virtual and Augmented Reality is to immerse the user 'in' the content, providing a sense of total envelopment (Figure 16 left). Immersivity is a function of the lack of perception of the medium which delivers the content: "as long as you can see the screen, you're not in virtual reality. When the screen disappears, and you see an imaginary scene [...] then you are in virtual reality" (Pimentel and Texeira, 1992, p. 7). The only difference in AR[3] is that the content does not occupy the entire field of view but instead merges with the real world still visible. For example, an AR headset can surround the user with swimming fish (Figure 16 right), creating the sensation of the room being an aquarium that surrounds the user - an immersive experience indeed!

The loss of awareness of the medium makes the user so engaged 'in' the content (with Virtual Reality) or 'with' the content (in Augmented Reality) to the point that they lose awareness of the device delivering it—be it a screen, the frame of goggles, or a projector. This immersion is so profound that the content feels self-existent and independent, seemingly detached from the medium through which it is presented.

[3] Current AR hardware does not allow a total disappearance of the medium, nor the coverage of the entire field of view. However, promising solutions to seamlessly integrate digital content with the user's natural field of vision, such as AR contact lenses, are already under development (Efron, 2023).

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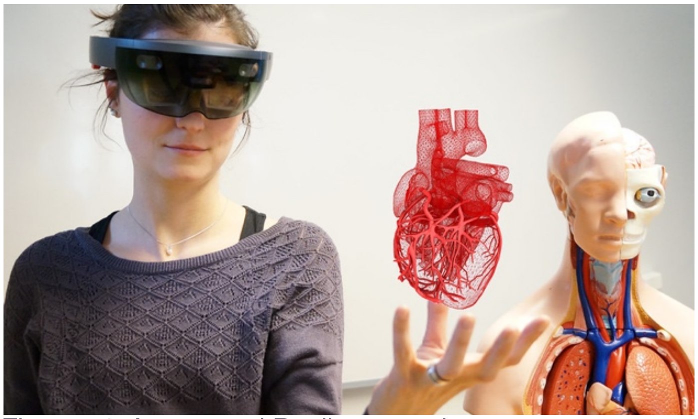
Table 3. Core and optional features of Augmented and Virtual Reality.

<table>
<tr><th>Augmented Reality</th><th>Virtual Reality</th></tr>
<tr><td>
Figure 14. Augmented Reality example.
Source: Valery Heritier on Flickr.</td><td>
Figure 15. Virtual Reality example.
Image source: XR Expo on Unsplash.</td></tr>
<tr><td>Core Features
• Immersivity
• Interactivity (spatial and physical)
• Situated Visualization</td><td>Core Features
• Immersivity
• Interactivity (spatial and physical)</td></tr>
<tr><td colspan="2">Optional Features
• Haptic feedback
• Spatial audio
• Body tracking
• Room scanning
• . . .</td></tr>
</table>

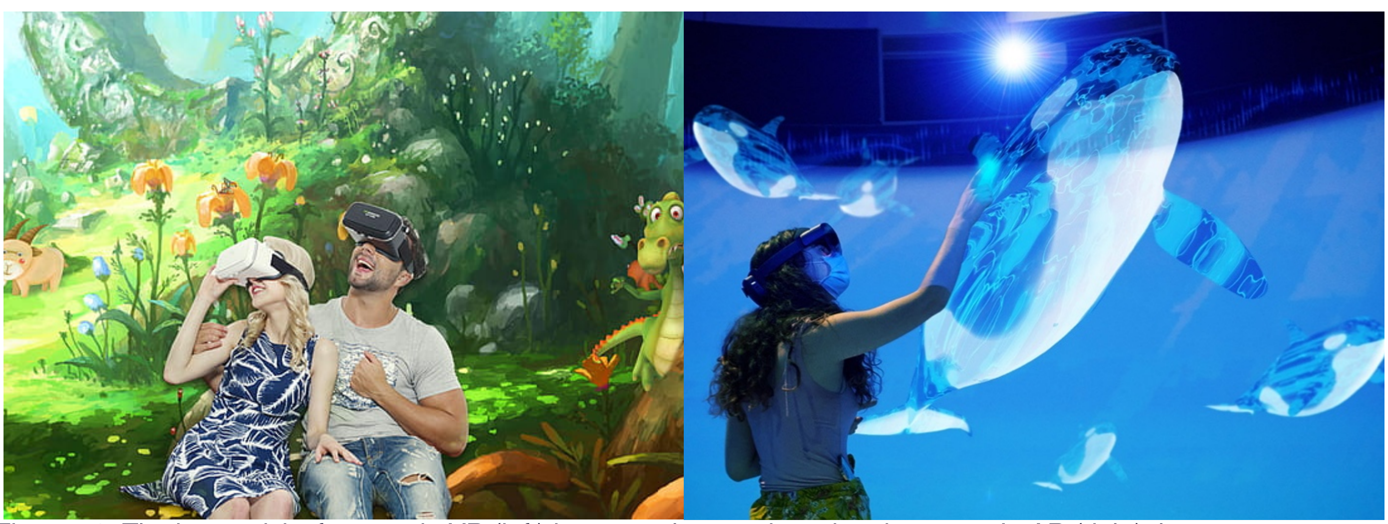


Figure 16. The immersivity features in VR (left) immerge the user in a virtual content. In AR (right) the user engages with the virtual content in the real world.
Images sources (left to right): Pickpic, and Andrew Harrington and Joshua Downs, Formative Co.

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2.3.2 Interactivity

Another core feature of these technologies is the unique level of interaction with digital content they offer. We separate interactivity features into two types:

Physical Interactivity: This enables users to manipulate digital objects using natural, intuitive gestures, as if they were interacting with real-world objects. It bridges the gap between the digital and physical realms, enhancing the sense of realism in the virtual environment (Figure 17 left).

Spatial Interactivity: This aspect allows users to navigate a virtual space. In Virtual Reality, it involves moving through and exploring entirely virtual environments. In Augmented Reality, it includes moving around in the real world while engaging with virtual content that appears to be part of the physical surroundings. This spatial immersion adds a layer of depth and context to the user experience, further blurring the lines between the virtual and real worlds (Figure 17 right).

Figure 17. The feature of physical interactivity lets the user move digital objects using natural gestures (left). Spatial interactivity lets the user move into a virtual space as the digital content spatially surrounds the individual (right). Images sources (left to right): Areous Ahmad, and RDNE Stock project on Pexels.

2.3.3 Situated visualization (AR only)

A unique core feature of Augmented Reality is its ability to visualize digital content in context with the physical world. This feature is also known as 'situated visualization' (Willett *et al.*, 2016). This feature allows placing content precisely where it is needed or preferred, enhancing access to information (Figure 18). Situated visualization can create the illusion that digital objects are part of the physical world, a capability which cannot be afforded by other digital tools, where access to digital content is typically confined to the surface of screens.

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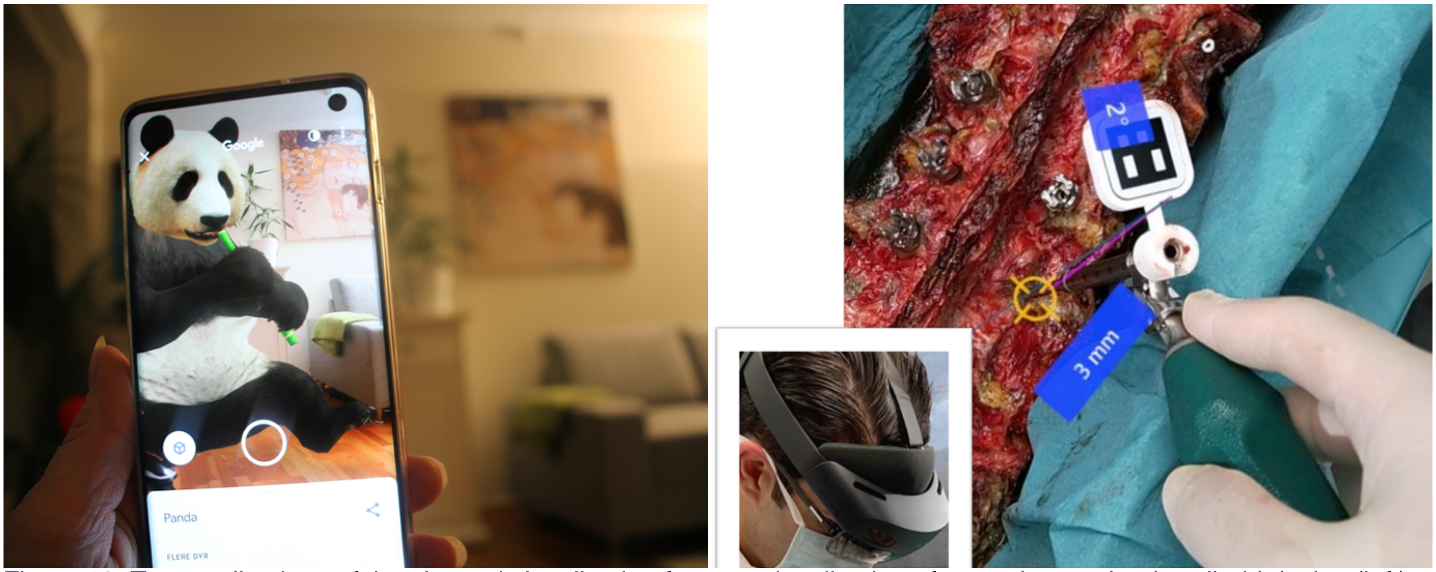

Figure 18. Two applications of the situated visualization feature: visualization of a panda trough a handheld device (left) and provision of information to a surgeon wearing an AR headset (right).
Images sources (left to right): Stina Åshildsdatter Grolid on NDLA, and Balgristwiki on Wikipedia.

2.3.4 Optional features of AR and VR

In exploring the core features of Augmented and Virtual Reality, we have identified several other optional features now often integrated with AR and VR devices. These include haptic feedback, which simulates tactile sensations; spatial audio, replicating real-world sound perception; body tracking, enabling the animation of avatars in virtual environments; and room scanning, used to make virtual objects interact with the real world. While improving the overall sensory experience, these features are still optional for many models.
Until a few years ago, VR and AR headsets did not include these capabilities, much like the first smartphones lacked cameras or fingerprint recognition. Just as cameras are now standard in smartphones but not exclusive to them, these immersive features (e.g., haptic feedback) have become more common in VR and AR devices but are not yet identifying features of these technologies. They represent emerging trends in immersive technology that is likely to become more integral as hardware evolves.

Although it appears contradictory, the lack of a universal and unchanging set of core features aligns with the dynamic nature of technology: its continuous evolution necessitates an ongoing process of refinement and adaptation of the features (DeSanctis and Poole, 1994). As immersive technologies advance, the distinction between core and optional features may shift, reflecting the technological progress and its impact on user experience.

The next section will show how the core features of Augmented Reality and Virtual Reality, as well as the strategic challenges presented in section 0, can be linked to the augmentation configurator. This exploration will complete the matching between challenges and features.

2.4 Targeting strategic challenges: the potential of AR and VR in strategic decision making

2.4.1 Translating AR/VR core features in implementation strategies

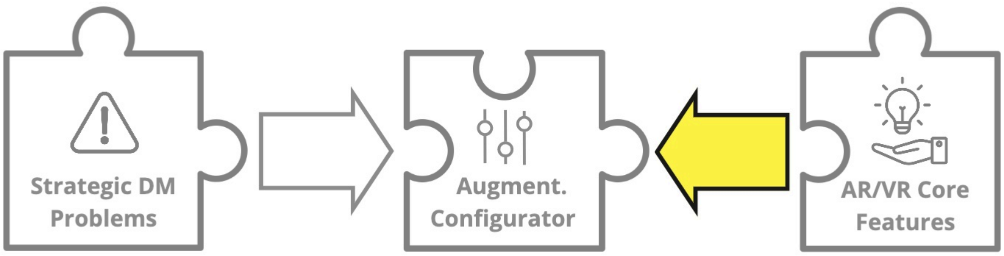

Figure 19. This section links the core features of AR and VR to the augmentation configurator.

The core features identified for AR and VR are now linked to the augmentation configurator (Figure 19), in particular to the implementation strategies from the field of Augmented Cognition. This exercise can be summarized by the questions: which AR/VR core features allow which implementation strategy to deliver cognitive augmentations? Or vice versa: which implementation strategies can be actuated leveraging the core features of AR and VR?

> **“ The implementation strategy in a cognitive augmentation is the way through which the aid is delivered to the user.**

To answer these questions, we analysed the implementation strategies found in the field of AC by Felicini and Mortara (2023a) and individuated those that can be actuated due to the core features of AR and VR.

Table 4 below summarizes the exercise while Table 5 provides compelling examples in support of the linking.

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An example of implementation strategy

Figure 18. Modern defibrillators are very simple to operate. They incorporate a cognitive augmentation which assists users by providing the required knowledge through a step-by-step instructions strategy. Image source: Commander, U.S. Naval Forces Europe-Africa/U.S. 6th Fleet on Flickr.

Implementation strategies, as defined by Felicini and Mortara (2023a), are ways to deliver a cognitive augmentation to the user of a tool. For instance, modern defibrillators include an augmentation which enhances the user's ability by providing essential knowledge (the augmentation) on how to operate the device. The strategy to deliver the augmentation involves prompting clear step-by-step instructions (the implementation strategy) about how to correctly place the pads on the patient's chest to safely activate the defibrillator. This strategy of augmentation provision ensures that even those without prior training (the limitation) can perform life-saving actions competently and confidently.

Table 4. Implementation strategies to deliver cognitive augmentations that can be delivered through AR and VR due to their core features. A glossary of the implementations is available in Table 9 (page 65).

IMPLEMENTATION STRATEGIES / CORE FEATURES			Addition of									Subtraction by				Modification of					
			Prompts			**Analysis**		**Cues**		**Experiences**		**Reduction**		**Delegation**		**Task elements**		**Info provision**		**Task executed**	
			Instructions	Motivational	Suggestions	Analytics	Evaluation	Audio Cues	Visual Cues	Live Logging	Virtual Simulation	Decluttering	Deferring	Automation	Repartition	Adaptivity	Gamification	Data Ergonomics	Multimodality	Diversification	Role Change
AR	VR	Immersivity								x	x						x				x
AR	VR	Interactivity															x	x			
AR		Situated visualization	x	x	x				x			x					x	x			

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Table 5. Examples of implementation strategies that can be achieved through the core features of AR and VR.

IMPLEMENTATION STRATEGIES	CORE FEATURES		
	Immersivity	**Interactivity**	**Situated visualization (AR)**
Prompts (instructions, motivational, suggestions)	/	/	An AR-enhanced language learning experience can highlight objects in the environment and provide corresponding words or phrases associated with the objects.
Visual cues	/	/	Head-Up Display (HUD) in a car can guide the driver by superimposing arrows, directional indicators, or highlighted paths on the real-world.
Experiences (Live logging, virtual simulations)	Users can immerse themselves in virtual simulations. For example, AR allows interaction with past events superimposed onto real-world historical sites. Conversely, VR provides a fully immersive journey into digitally reconstructed historical events. Additionally, both technologies support live logging. For instance, AR can re-enact past meetings in their original settings with digital representation of participants, while VR can offer a 360-degree immersive reproduction of past recorded meetings.	/	Via an AR experience we can overlay a virtual reconstruction of how an archaeological manufact might have looked in its original setting, and viewers could witness related historical events.
Decluttering	/	/	Customers engaged in an AR shopping experience can effectively filter out all irrelevant products, focusing solely on the items they are seeking.
Gamification	AR game elements can appear all around the room to transform any space in a playfield. The total immersivity in VR can 'transport' players into space and let them assume the role of astronauts.	An AR or a remote VR training experience can assign additional tasks for the trainees involving the assembly of virtual components, creating a gamified training experience.	In a gamified running experience AR elements can appear, challenging the runner to "collect" virtual rewards or avoid obstacles.
Data ergonomics	/	In AR a technician repairing a machine or, in VR, a video gamer within an immersive game, can dynamically reposition instructions to a more convenient location within their field of view.	The AR interface can provide real-time data and instructions directly in a repair technician's field of view, eliminating the need to consult manuals or look at separate screens whilst performing a repair.

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(continued)

IMPLEMENTATION STRATEGIES	CORE FEATURES		
	Immersivity	**Interactivity**	**Situated visualization (AR)**
Role change	VR and AR can support users to experience unfamiliar situations in first person to stimulate their empathy. For example, users can experience in first person traumatic experiences such as that of those displaced by humanitarian disasters.	/	/

2.4.2 Cognitive limitations behind strategic management challenges

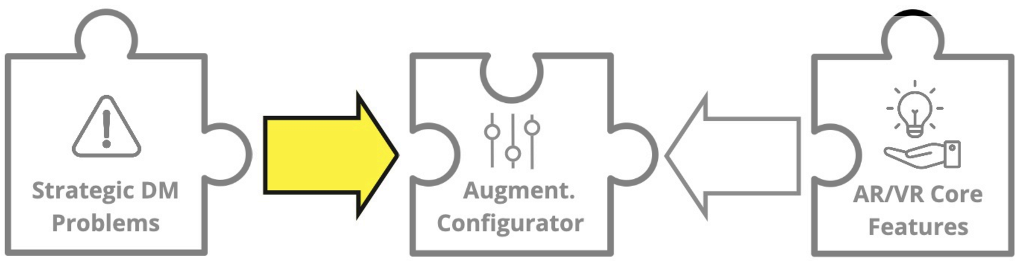

Figure 20. This section links the core features of AR and VR to the augmentation configurator.

The implementation of SMTs is inherently complex, with cognition playing a pivotal role. Human cognitive flaws and limitations are at the core of numerous challenges, whether they pertain to human interactions, to the management of the content or involve the processes required to engage with SMTs effectively.
Hence, cognitive limitations apply to many of the issues discussed in section 0, beyond those explicitly labelled as psychosocial behavioural. This section links the strategic decision-making challenges with the cognitive limitations listed in the augmentation configurator (Figure 20).

Consider the example of a facilitator in the familiar example of a roadmapping workshop. The role of a facilitator in a workshop is primarily to guide and manage the group dynamics to ensure an effective and productive session. A key challenge is **'facilitation load'** which stems from several factors. One is managing extensive information on the roadmap while actively participating in the workshop, straining the facilitator's **working memory**. A facilitator cannot take care of the numerous exchanges happening in the workshop all at once (**psychomotor bottleneck**) nor perceive all that happens in the conversations around the room (**perceptual bottleneck**). Furthermore, the facilitator's **memory capacity** is finite, presenting a constraint compared to the potentially extensive discussion content exchanged during workshops. While expertise in facilitation certainly aids in navigating conversations and managing diverse situations, this proficiency is cultivated over time, and not everyone possesses the seasoned skills of a facilitator. Hence a **lack of**

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expertise necessitates heightened vigilance and sustained alertness, thereby imposing additional complexity and demand on the facilitator's role.

This example illustrates how a single strategic challenge can be linked to multiple cognitive limitations, each potentially requiring a specific augmentation for resolution. Table 6 below outlines our mapping of the cognitive limitations pertaining to the strategic challenges identified in Part 1 of the report.

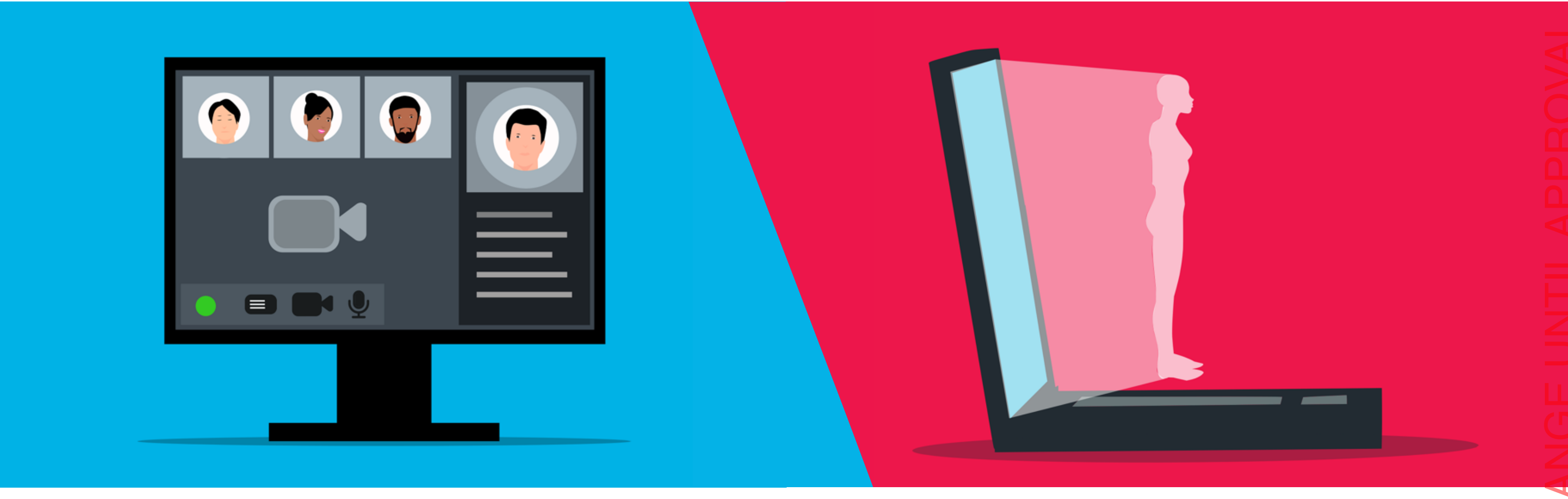
> **Cognitive limitations play a role in various challenges, beyond the explicit cognitive issues.**

This section introduced the final component of the report, designed to help integrate AR and VR technologies into overcoming challenges during the implementation of SMTs. The following section will present practical applications of these insights in real-world examples.

Table 6. The cognitive limitations behind the strategic challenges individuated. A glossary of the terms for the limitations is available in the appendix, Table 9, page 65, and for the challenges in Table 1, page 28.

STRATEGIC CHALLENGES		LIMITATIONS	Physical limits		Bias[4]	Cognitive bottlenecks: Info processing			Cognitive bottlenecks: Info storage		Cognitive bottlenecks: Mental state		Missing knowledge	
			Costly Simulation	Variable Performance	Anchoring	Working Memory	Psychomotor Bottleneck	Perceptual Bottleneck	Memory Fault	Memory Capacity	Low Engagement	Incorrect Focus	Lack Of Expertise	Lack Of Information
Content-related	**Data Management**	Clustering				x		x				x	x	
		Data Security												
		Knowledge Loss							x	x		x		
		Making Connections				x		x				x	x	x
		Prioritization			x								x	x
	Input Quality	Defining KPIs											x	x
		Info Overload				x								
				x							x	x	x	x
		Low Creativity									x	x		
		Granularity Level											x	x
		Lack of Analysis											x	x
		Lack of Knowledge												x
		Unclear Scope									x	x	x	x
	Vision	Template Customisation											x	
		Roadmap Evaluation											x	
		Uncertainty Managmt	x			x		x					x	x
		Vision Definition			x			x			x		x	x
		Alignment to Vision			x						x			
Process-related		Facilitation Load				x	x	x		x			x	
		Process Customisation											x	
		Process Understanding									x	x	x	x
		Roadmap(ping) Neglect			x				x		x		x	
		Voting												
	Workshop-Related	Attendance Quality									x			
		Equipment Disruption												
		Resources Availability												
		Travel Risks												
Psychosocial	**Biases**	Anchoring			x									
		Psychological Distance			x						x	x		
		(Other) Individual Biases												
		Disruptive Behaviour									x	x		
		Limited Participation			x						x	x		
		Social Influence												
		Trust			x						x		x	
Tool-Related		Accessibility						x						
		Digital Learning Curve											x	
		Lack of Digitization											x	
		Tele-Meetings											x	

4 Additional category integrated in this report, not present in the original tables from Felicini and Mortara (2023a). See page 27.



2.5 Implementing the insights: practical applications

Now that the SMTs implementation challenges underpinned by cognitive problems have been linked to limitations (see Table 6), and the core features of AR/VR can be translated in implementation strategies (see Table 4), it is possible to *use* the augmentation configurator as a two-way device to design digital tools leveraging such technology to address the known challenges.
The graphical representations in Figure 21 and Figure 22 (pages 51-52) illustrate the application of the configurator in designing AR/VR solutions for the listed challenges.
Below are seven practical examples, each situated within a roadmapping context. For illustrative purposes, these examples correspond to each of the implementation techniques afforded by the core features of AR and VR.

Example 1 (Blue path)

PROBLEM: Making connections between concepts while using a strategic management tool (e.g., a roadmap) means linking, graphically and mentally, inputs present in the tool to build a narrative, answer questions, understand priorities, etc. This exercise can prove difficulty depending on the complexity of the matter. A **lack of expertise** in this kind of exercise can certainly exacerbate the problem.
SOLUTION EXAMPLE: An AR tool can seamlessly superimpose **action suggestions** pertaining to the ongoing discussion onto the surface of the SMT in use. These **suggestions**, serving as sources of inspiration, could help understand connections between concepts and fragments of information, thereby fostering a more engaging and meaningful facilitation in real time.
This feature can be readily achievable into existing digital whiteboard software during remote workshops. The advantage of using AR is in the unique core feature of **situated visualization**, which would not constrain the suggestions to the screen but overlay them to the printed roadmapping canvases during in-person workshops, or even while participants move around the room engaging in conversations.

Example 2 (Purple path)

PROBLEM: Understanding the process of using an SMT such as roadmapping can be a challenging task. It may require multiple iterations to master the technique and annotate the right contribution in the right place at

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the right time. A **lack of expertise** can lead to inefficient contributions and potentially jeopardize the outcomes of the exercise.
SOLUTION EXAMPLE: An AR system can provide **action corrections** to inexperienced participants projecting **visual cues** to highlight the mistake (e.g., highlighting a post-it appended in the wrong layer during a roadmapping workshop). This will save attentional resources and allow facilitators to shift their focus to more strategic aspects. As mentioned in the previous example, the advantage of using AR would lie in its portability beyond the screen. The **situated visualization** feature will ensure that the augmentation remains consistently accessible during in-person workshops.

Example 3 (Green path)

PROBLEM: Managing all the information from the discussions during a roadmapping workshop can easily be overwhelming given the breath and variety of topics that can be touched upon. The **information overload** may stem from the inherent limits of the **working memory** humans can rely on.
SOLUTION EXAMPLE: Masking part of the information displayed in the SMT will allow to exclude irrelevant information, focus on specific aspects and **reduce the task load**. This **decluttering** functionality will rely on the **situated visualization** feature of AR.

Example 4 (Red path)

PROBLEM: Creativity is a fundamental component in innovation, acting as the driving force behind the formulation of inventive solutions and the cultivation of novel ideas. This holds true in roadmapping as well, particularly when envisioning the future that needs to be crafted. A **lack of creativity** could derive from a state of **low engagement** with the topic under discussion.
SOLUTION EXAMPLE: An approach to reignite participant creativity can be to induce a **cognitive change** by encouraging participants to **change role** and embody the perspective of a future customer. Harnessing the **immersivity** feature of virtual reality can be a solution in this context. By transporting participants into a virtual scenario, VR enables them to assume the role of a potential customer or envision themselves as future citizens in our evolving society. This can revitalize the discussion and unlock fresh perspectives, thus enriching the overall creative discourse.

Example 5 (Yellow path)

PROBLEM: In a corporate setting, a critical challenge is having a notable misalignment between the company's vision and the perspective of employees. This **misalignment of visions** can be attributed to a **low engagement**, resulting in a lack of enthusiasm and commitment among the workforce.
SOLUTION EXAMPLE: The **immersivity** feature of VR provides a unique opportunity to **simulate** scenarios that bring the corporate vision to life in a tangible and experiential manner. This **virtual simulation** vividly illustrates the company's vision, fostering a deeper connection and understanding of the organizational goals.

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Example 6 (Pink path)

PROBLEM: During the implementation of SMTs, active participant involvement is pivotal for a robust strategic conversation. While the tool typically serves as a framework around which to build the conversation, a **limited participation** may lead to shallow contributions, impacting the exercise outcomes. This can stem from a state of **low engagement** from the participants.
SOLUTION EXAMPLE: A solution can be to **capture the attention** by integrating **gamification** elements into the SMT, such as animations or cartoonified information. By leveraging the **interactivity** feature of immersive technology, whether through Augmented Reality (AR) on printed canvases or entirely virtual exercises (VR), the SMT can be transformed from a mere template into an interactive artifact that stimulates meaningful contributions.

Example 7 (Brown path)

PROBLEM: The **perceptual bottleneck** of humans can be exacerbated by **accessibility issues** during workshops. In roadmapping sessions, where a strategic landscape roadmap might span an entire wall, contributors may face challenges in consulting the canvas when gathered around it. Additionally, individuals with visual impairments may struggle to read others' written contributions.
SOLUTION EXAMPLE: Implementing **data ergonomics** via the **situated visualization** of Augmented Reality can effectively counter these challenges. By displaying this **knowledge provision**, such as details about a colleague's input, directly within the user's field of view, AR ensures all participants have equal access to necessary data. This ensures that participants, regardless of their position in the room or any visual impairment, can seamlessly access and engage with pertinent information during workshops or conversations.

In summary, the presented examples highlight potential applications of immersive technologies in the implementation of SMTs. It is crucial to acknowledge that these examples are speculative, and other factors beyond challenges and features of the technology must be taken into consideration. Notably, the technology's maturity stands out as a significant barrier to the widespread adoption of Augmented and Virtual Reality. Similarly, the generation of content and the required skills to make it can also slow the diffusion of these tools. Other technologies such as generative AI are fundamental in this aspect. While the proposed examples are conceptually valid and intriguing for organizational integration, practical problems such as headset comfort, battery life, and motion sickness currently impede broader technology acceptance of AR and VR.

Nevertheless, the report's strength lies in its theoretical foundations, based on the analysis of the core features of AR and VR, and on their application to aid cognitive limitations, making it enduring and applicable as hardware evolves. Being based on technology's core features rather than its technical developments, the insights remain relevant and are poised to endure, anticipating a future where AR and VR seamlessly integrate into common eyewear. Until then, the examples remain visionary proposals, yet as hardware advances, their feasibility is expected to increase.

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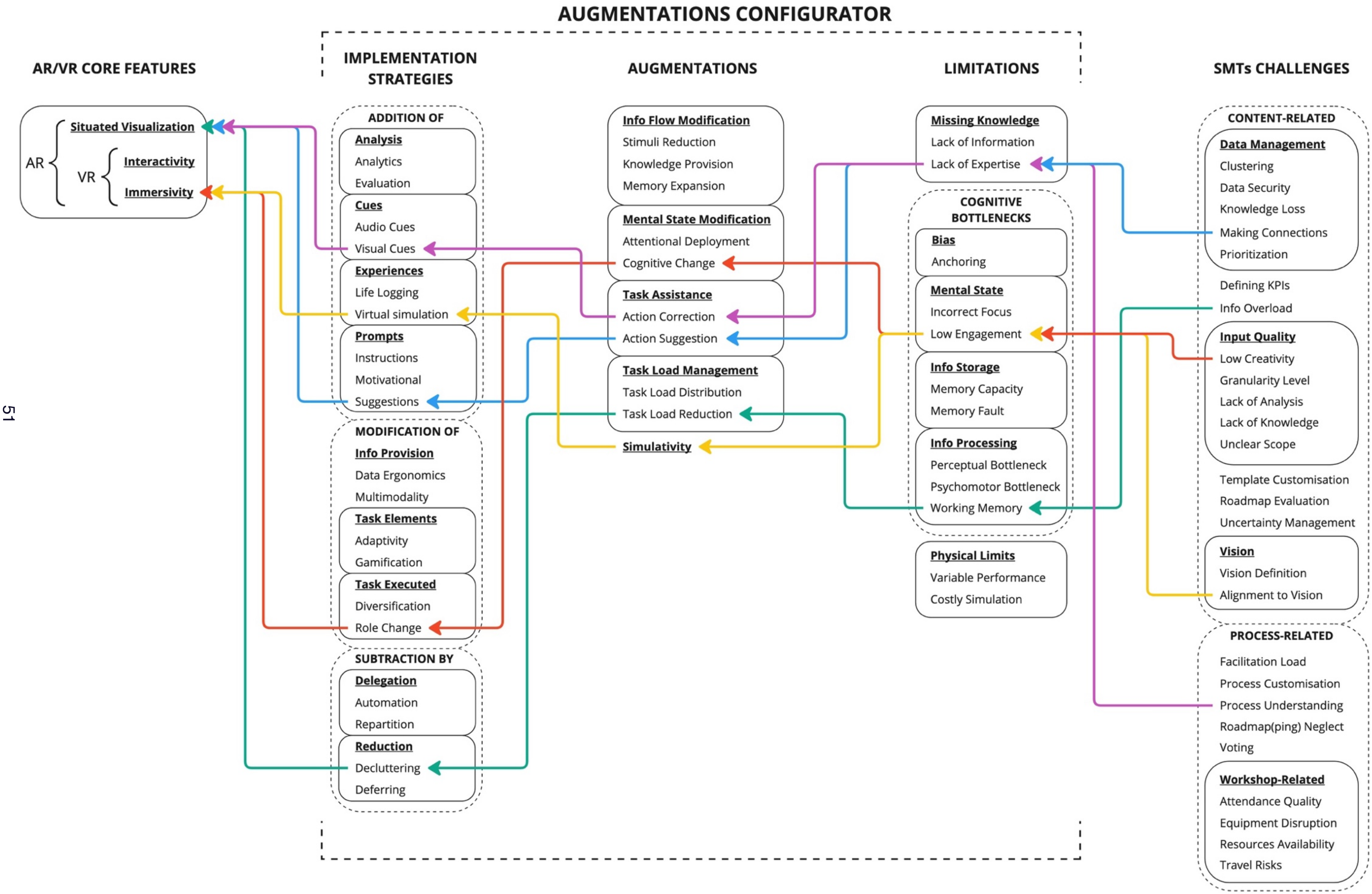

Figure 21. Graphical representation of how the augmentation configurator is used to design AR/VR solutions for strategic management challenges.

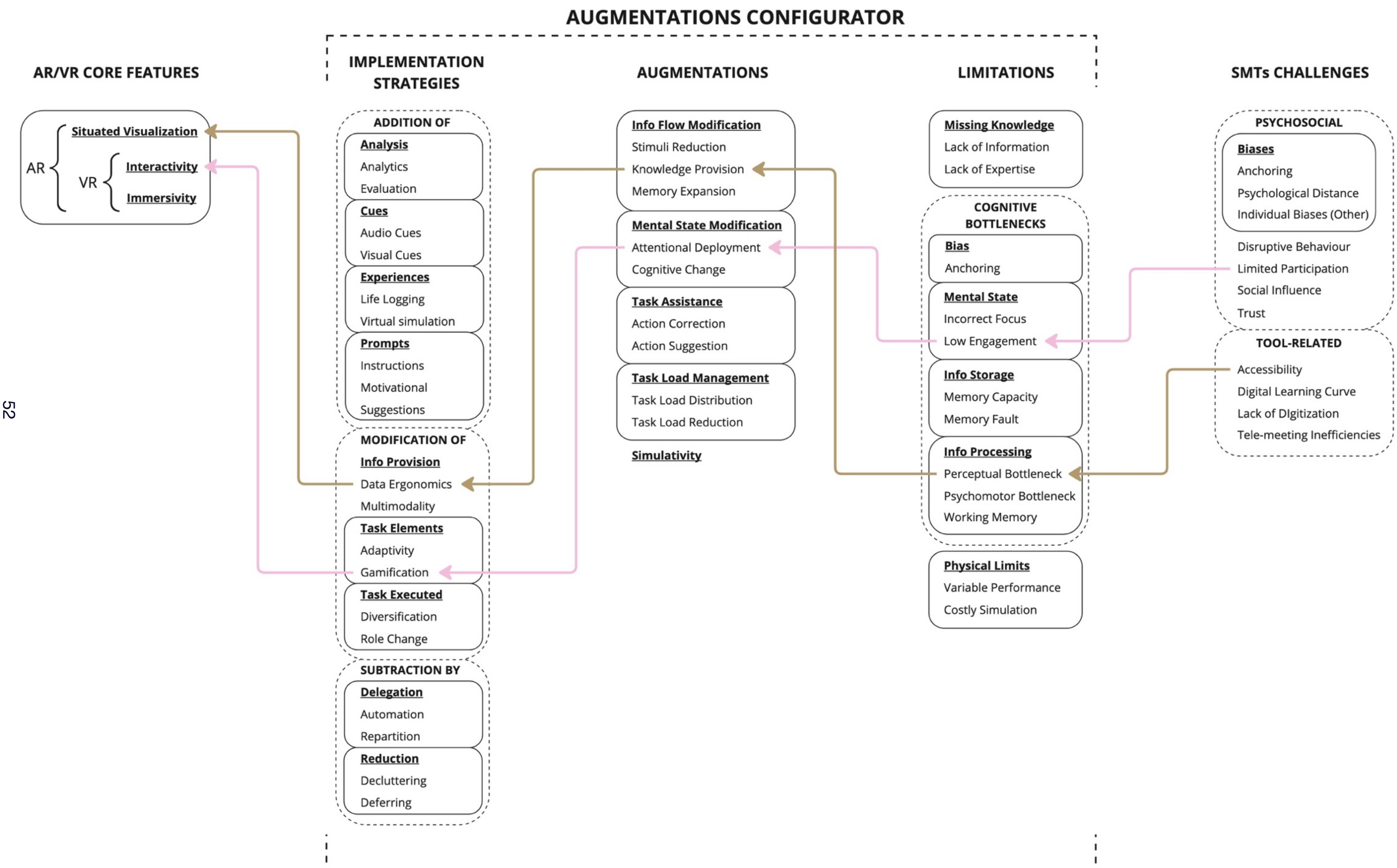

Figure 22. Graphical representation of how the augmentation configurator is used to design AR/VR solutions for strategic management challenges.

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2.6 Future directions

This final section outlines some key directions for future research, each offering unique opportunities to apply, enhance and expand upon the insights presented in this report.

Broader application in other strategic management practices…

This report sets out a configurator for cognitive augmentations in the realm of Strategic Management Tools (SMTs) implementation. Future research should focus on extending this process to other strategic management practices, for instance in strategy-making. This expansion involves identifying the unique challenges within strategy-making and using the configurator to address these challenges. By referencing the methodology used in section 2.4.2 of the report, researchers can tailor the configurator to new challenges, thereby demonstrating its versatility and effectiveness across various strategic management domains.

… and of other emerging technologies

The technology-agnostic nature of the configurator presents an opportunity to use the integration process with other emerging technologies, beyond and/or on top of AR and VR. For instance, Artificial Intelligence is likely to be pivotal in the generation of the digital content to be displayed via VR and AR. Future studies should test the configurator with other technologies by identifying the core features of new tools, link them to the implementation strategies of augmented cognition, as done in section 2.4.1, and potentially combine their features with those of AR & VR.

Evaluating the effectiveness of cognitive augmentations…

As observed by Felicini and Mortara (2023a) there is a lack of recognized metrics for measuring cognitive augmentations and a clear need for a robust evaluation framework. This report is a designer tool that facilitates the exploration of new augmentation combinations, which will then need to be evaluated. By distinguishing technology features, cognitive limitations, and augmentation characteristics, it will help future studies in comparing different applications and evaluating their effects effectively.

…and the impact of immersive technologies on knowledge processes

An aspect worth monitoring is the potential impact of immersive technologies on social interactions, decision-making processes, and information access within organizations. Similar to the transformative effects of remote working during the pandemic, applications such as holographic dashboards or VR workshops, once adopted, could revolutionize office environments, workflows, and interpersonal dynamics. Research in this area could yield crucial insights into how immersive technology reshapes work culture and collaboration.

Integrating diverse forms of augmentations

The configurator's modular design allows for the incorporation of various augmentation types, for instance sensory or social augmentations (De Boeck and Vaes, 2021). Future research should explore the integration of these diverse augmentations with the configurator to address challenges in strategic management. This integration could facilitate innovative solutions, matching together new technological advancements and traditional strategic management issues.

Monitoring the Evolution of core features in AR and VR

The evolving nature of AR and VR technologies will require future studies to consider changes, observing how the distinction between core and optional features evolves and identifying emerging new features. This is crucial for understanding how advancements, such as those in haptic technology, will become integral to immersive reality and subsequently deliver new opportunities of augmentation in strategic management practices.

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Appendix

Table 7. Limitation-Augmentation quadrant of the configurator: it links the Augmentations proposed with the Limitations encountered. Each number corresponds to an occurrence of that combination from the AC literature (Felicini and Mortara, 2023b) listed in the references section (page 60)*, while (*) indicates hypothetical combinations, listed in Table 10 (page 67). A glossary of the categories is available in Table 9 (page 65).*

AUGMENTATIONS \ LIMITATIONS		Physical limits		Cognitive bottlenecks: Bias[5]	Cognitive bottlenecks: Info Processing			Cognitive bottlenecks: Info storage		Cognitive bottlenecks: Mental state		Missing knowledge	
		Costly Simulation	Variable Performance	Anchoring	Working Memory	Psychomotor Bottleneck	Perceptual Bottleneck	Memory Fault	Memory Capacity	Low Engagement	Incorrect Focus	Lack Of Expertise	Lack Of Information
Task Assistance	Action Correction		[1]	[69*]		[2]						[3]	
	Action Suggestion		[4]	[70*]	[5]	[6]	[7]	[53*]		[58*]	[8]	[63*]	[3]
Task Load Management	Task Load Distribution		[9]		[10]	[6]	[5]				[62*]	[64*]	[67*]
	Task Load Reduction		[11]		[12]	[13]	[10]	[14]	[56*]	[59*]		[15]	[16]
Mental State Modification	Attentional Deployment		[47*]	[71*]	[17]			[54*]		[60*]	[5]		
	Cognitive Change		[18]	[72*]	[48*]	[49*]	[19]	[52*]	[57*]	[20]	[21]		
Info Flow Modification	Stimuli Reduction				[22]	[50*]	[51*]			[61*]	[5]	[65*]	
	Knowledge Provision		[23]	[73*]	[24]	[13]	[25]	[3]		[26]		[27]	[28]
	Memory Expansion								[16]				
Simulativity		[29]		[74*]				[55*]		[30]		[66*]	[68*]

5 Additional category integrated in this report, not present in the original tables from Felicini and Mortara (2023a). See page 27.

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Table 8. Augmentation-Implementation quadrant of the configurator: it links the Augmentations with the Implementation Strategies tested. Each number corresponds to an occurrence of that combination from the AC literature (Felicini and Mortara, 2023b) listed in the references section (page 60)*, while (*) indicates hypothetical combinations, listed in Table 10 (page 67). A glossary of the categories is available in Table 9 (page 65).*

AUGMENTATIONS	IMPLEMENTATION STRATEGIES	Addition of									Subtraction by				Modification of					
		Prompts			**Analysis**		**Cues**		**Experiences**		**Reduction**		**Delegation**		**Task Elements**		**Info Provision**		**Task Executed**	
		Instructions	Motivational	Suggestions	Analytics	Evaluation	Audio Cues	Visual Cues	Life Logging	Virtual Simulation	Decluttering	Deferring	Automation	Repartition	Adaptivity	Gamification	Data Ergonomics	Multimodality	Diversification	Role Change
Task Assistance	Action Correction	[3]	[80*]	[2]	[84*]	[3]	[93*]	[3]	[97*]											
	Action Suggestion	[31]		[32]	[85*]		[94*]	[7]			[102*]									
Task Load Management	Task Load Distribution	[75*]		[81*]	[86*]				[98*]			[10]	[33]	[34]	[15]				[111*]	
	Task Load Reduction	[76*]		[13]	[35]				[98*]		[25]		[36]	[107*]	[15]		[10]	[10]		[112*]
Mental State Modification	Attentional Deployment	[77*]	[79*]	[82*]	[87*]	[90*]	[33]	[37]			[102*]					[110*]	[10]	[38]	[39]	
	Cognitive Change	[78*]	[18]	[83*]	[88*]	[91*]	[95*]	[96*]	[99*]	[100*]	[103*]	[104*]			[108*]	[20]			[21]	[40]
Info Flow Modification	Stimuli Reduction				[41]						[22]	[105*]	[106*]	[107*]	[109*]					
	Knowledge Provision	[27]		[42]	[43]	[92*]	[7]	[44]	[25]	[101*]					[26]		[45]			
	Memory Expansion								[16]											
Simulativity					[89*]					[46]										

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Table 9. The categories of the AC taxonomy and their description.

LIMITATIONS	
Anchoring[6]	The tendency to rely too heavily on the first piece of information encountered when making decisions.
Costly simulation	A simulation of an event, experience, object, etc. (e.g., for training) that would be complex, impossible, risky, or expensive to run.
Incorrect focus	The operator's attention is directed to a low-relevance aspect given the task at hand.
Lack of expertise	Lack of skills or wisdom required to optimally perform the task.
Lack of information	Missing information or knowledge from the user.
Low engagement	Low motivation from the user towards the task at hand.
Memory capacity	Limited amount of information which can be stored by the human memory.
Memory fault	Failure to retrieve previously memorized information.
Perceptual bottleneck	Limited stimuli that can be perceived by the attentional resources, at the same time or in a prolonged period. [47]
Psychomotor bottleneck	Limit of the stimuli that can be processed at the same time (e.g., "[…] *The user knows what to do but is incapable of keeping up with the task load*" [5]).
Variable performance	Quality and quantity of performance variates in time or between individuals (e.g., human error).
Working memory bottleneck	Limit of the information the brain can temporarily store and manipulate for executive functions [48].
AUGMENTATIONS	
Action correction	Evaluation of a performed action and/or recommendation of the optimal way of execution (i.e., how to do it).
Action suggestion	Recommendation of the action to be taken (i.e., what to do).
Attentional deployment	Call the attention of the operator and/or direct it towards the most relevant aspects in the given situation.
Cognitive change	Induced change of the state of mind, mood, perspective, attitudes of the user.
Knowledge provision	Provision of previously unknown information.
Memory expansion	Increased amount of information that can be stored and retrieved.
Simulativity	Artificial simulation of events, situations, experiences, objects, roles, spaces, etc.
Stimuli reduction	Decrease in the amount of stimuli, through any of the human senses, to which the operator is subject to.
Task load distribution	Distribution of the user's effort over time (e.g., scheduling, delaying tasks) or between operators (e.g., collaboration). The overall effort doesn't vary.
Task load reduction	Reduction of the user's effort to complete a task.
IMPLEMENTATION STRATEGIES	
Adaptivity	Adjustment of a task or some of its aspects (e.g., difficulty, content) according to the situation.
Alerts/audio cues	Audio signals, tones, messages.
Analytics	Automatic elaboration, sorting, summarization, extraction of patterns, and insights from data.
Automation	Delegation to a machine of a task of part of a task.
Data ergonomics	Visualization, positioning, expression of information in ways/locations that makes data more understandable, manageable, memorable.

[6] Additional category integrated in this report, not present in the original tables from Felicini and Mortara (2023a). See page 27.

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(continued)

Decluttering	Reduction of the amount of information that is visualized or transmitted.
Deferring	Postponing of communications, inputs, and tasks to a later time.
Diversification	Change of user activity.
Evaluation	Assessment of a performed activity/outcome.
Gamification	Insertion of game/interactive elements in the activity.
Instructions	Prescriptive information to guide actions.
Life logging	Capture/recording and retrieval of events/information.
Motivational	Encouragement to take or keep performing an action. Incentive towards a specific attitude or mental state.
Multimodality	Advantage deriving from the provision of information using multiple senses (visual, audio, tactile, etc.)
Repartition	Distribution of the task effort between multiple operators.
Role change	Taking over the role of someone else.
Suggestions	Provision of information in a non-prescriptive way.
Virtual simulation	Artificial simulation of events, situations, experiences, objects, roles, spaces, in a virtual environment.
Visual cues	Graphic symbols, lights, indicators, pointers.

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Table 10. Hypothetical combinations of augmentations, limitations, and implementations in the field of AC.

AUGMENTATIONS – LIMITATIONS (Hypothetical)	
47	When an excessive **variation in the performance** is detected, the augmentation **recalls the attention** of the operator to the task and/or its variable performance.
48	In situations of **elevated workload**, the augmentation actively **fosters a distinct mindset** (e.g. promoting heightened awareness or facilitating a state of flow).
49	In the presence of **excessive stimuli**, the augmentation actively **fosters a distinct mindset** (e.g. promoting heightened awareness or facilitating a state of flow).
50	In the presence of **excessive stimuli**, the augmentation **reduces the quantity of information** presented to the operator.
51	In the presence of **excessive stimuli**, the augmentation **reduces the amount of received information** with the aim of promoting perception of the filtered stimuli.
52	If the operator **struggles to recall previously memorized information**, the augmentation can **induce a mental state** conducive to memory retrieval and promoting recollection.
53	When the operator **fails to retrieve previously memorized information**, the augmentation **suggests actions** that are related to the lost information to stimulate recall.
54	When the operator **fails to retrieve previously memorized information**, the augmentation **calls the attention** to surrounding objects or events that are related to the lost information to stimulate recall.
55	When the operator **fails to retrieve previously memorized information**, a **simulation** could (re)create objects or events that are related to the lost information to stimulate recall.
56	To increase **the amount of information which can be stored** by the human memory, the augmentation **reduces the cognitive load** by organizing the information in a way that is easier to memorize.
57	To increase the **amount of information which can be stored** by the human memory, the augmentation **promotes a cognitive state** that stimulates and favors memorization.
58	To **increase the motivation** of the operator towards the task, the augmentation **suggests actions** to stimulate participation and enthusiasm.
59	To **increase the motivation** of the operator towards the task, the augmentation **reduces the load of the task** to stimulate participation and enthusiasm.
60	To **increase the motivation** of the operator towards the task, the augmentation **calls the attention** to specific elements of the task to stimulate participation and enthusiasm.
61	To **increase the motivation** of the operator towards the task, the augmentation **reduces the stimuli** received making the task more accessible and stimulate engagement.
62	The augmentation **distributes the task load** making easier for the operator to **pay attention** to a high-relevance aspects of the task.
63	If the operator **lacks the required skills**, the augmentation **suggests the optimal action** to perform.
64	If the operator **lacks the required skills**, the augmentation **reassigns the task** to someone with the requisite qualifications.
65	If the operator **lacks the required skills**, the augmentation intervenes by **reducing stimuli** to enhance the task's manageability.
66	If the operator **lacks the required skills**, a **simulation** can provide training to enhance proficiency.
67	If the operator **lacks the required information**, the augmentation **reassigns the task** to someone with the requisite knowledge.
68	If there is a **lack of information** about a phenomenon, a **simulation** could model potential scenarios, offering hypothetical knowledge and insights.
69	If **anchoring** is detected in the actions of the user, **action corrections** can mitigate the effect of the bias.
70	If **anchoring** is detected in the actions of the user, the augmentation can **suggest actions** to mitigate the effect of the bias.
71	**Calling the attention** to specific items or tasks can mitigate the **anchoring** of the user towards other ones.
72	**Increasing awareness** of the current mental framework and biases in action can reduce the impact of **anchoring.**
73	**Providing information** about certain items can mitigate the **anchoring** of the user towards other ones.
74	Allowing the user to experience events through **simulations** can mitigate the **anchoring** to other events.

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AUGMENTATIONS-IMPLEMENTATIONS (Hypothetical)	
75	The **task load is distributed** by giving **instructions** about different segments of the task to different operators.
76	The **task load is reduced** by giving **instructions** for a portion of the task to be performed.
77	**Instructions** guide the operator on **where to focus** their attention.
78	**Instructions** can foster **cognitive change** by directing individuals to adopt new thought patterns or approaches.
79	**Motivational** messages can encourage the operator to **focus on specific tasks and goals**.
80	**Motivational** messages can inspire individuals to **rectify mistakes** and improve performance.
81	**Suggestions** can provide guidance on effectively **distributing the workload** among operators.
82	**Suggestions** can guide **attentional deployment** by directing individuals toward specific focal points or tasks.
83	**Suggestions** can induce **cognitive change** by suggesting alternative approaches or different interpretations of situations, prompting operators to reconsider their cognitive frameworks.
84	**Analytics** tools can **identify patterns, trends, and anomalies in performance** metrics and identify areas where actual performance deviates from established benchmarks.
85	**Analytics** can provide **action suggestions** by leveraging data-driven insights to recommend specific actions or strategies.
86	**Analytics** tools can assess team members' workloads, identify bottlenecks, and **allocate tasks** based on each team member's skills and capacity.
87	**Analytics** can provide **attentional deployment** by highlighting key insights, areas and tasks that require attention.
88	**Analytics** can contribute to **cognitive change** by offering insights and data-driven information that challenge or reshape existing cognitive frameworks.
89	**Analytics** can incorporate **simulation** models to predict and simulate various scenarios based on historical data and mathematical algorithms.
90	**Evaluation** can guide **attentional deployment** by highlighting anomalies in performance that deviates from established benchmarks.
91	**Evaluation** can foster **cognitive change** by providing individuals with feedback on their performance.
92	**Knowledge provision** can be provided through **evaluation**, as systematic assessment of effectiveness and outcomes.
93	**Audio signals** can indicate the necessity for **corrective action**.
94	**Audio cues** can **suggest actions** by conveying specific information or signals through sound.
95	**Auditory stimuli** may encourage operators to shift their focus, reduce stress, and **promote a suitable mental state** over time.
96	**Visual cues** may represent symbolic images or metaphors that prompt individuals to **reframe their thoughts or emotions**.
97	**Life logging** can foster **action correction** by providing individuals with recordings about their behaviours and performances. By reviewing these records, individuals can identify areas for improvement.
98	By **documenting their life experiences**, individuals can **defer or bypass immediate tasks** with the assurance that they can access that information later at any point.
99	Regularly **documenting and reviewing life experiences** can **foster self-awareness** and facilitate reflective practices.
100	Exposure to **simulated diverse perspectives and experiences** can **influence cognitive patterns** and promote a better understanding of alternative viewpoints.
101	**Virtual simulations** can **provide knowledge** by creating experiential learning.
102	Selectively **occluding certain elements directs attention** toward the remaining visible components, guiding individuals to focus on specific aspects and **suggesting associated actions**.
103	A **decluttered space** without unnecessary stimuli can lead to **better cognitive strategies** and mental frameworks.
104	**Deferring actions** can stimulate **cognitive change** by allowing individuals the time and mental space to reflect, gather additional information, and consider alternative perspectives.
105	**Stimuli reduction** can be achieved through **deferring** by intentionally delaying exposure to certain stimuli or information.
106	**Stimuli reduction** through **automation** involves leveraging automated systems to minimize unnecessary sensory inputs or cognitive demands.

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107	**Task load reduction** through repartition involves strategically **redistributing components of a task, or sensory stimuli**, among individuals or systems to alleviate cognitive burdens.
108	**Adaptivity** of a task can challenge individuals to continually adjust, learn, and grow. This ongoing process fosters **cognitive change** by stimulating different mindsets.
109	A **task can be adapted** to provide a **variable amount of stimuli** according to the operator's state.
110	Introducing **gamification** to specific aspects or elements of a task can **captivate the attention** of operators.
111	**Diverse tasks** can be strategically incorporated into an activity to **distribute the workload** over time.
112	**Task load reduction** through **role change** involves redistributing responsibilities and roles among team members to reduce cognitive burdens.

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