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External representations in strategic decision-making: Understanding strategy's reliance on visuals

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Abstract

Research Summary: External representations, particularly visuals, are important in strategic decision-making. However, their pervasiveness and impact are not well understood in the strategy literature. Based on cognitive science research, we identify four cognitive functions crucial to strategic decision-making that benefit from using external representations. We also propose a conceptual model and propositions that explain how the quality of strategic decision-making depends on the interactions among task environment, external representations, and managers. We show that external representations influence in predictable ways the boundedly rational process of searching for new strategies. Key determinants include the manager's representational capability and the usability and malleability of the external representation. We discuss implications for users, designers, and teachers of external representations in strategy, as well as suggest avenues for future research.

Managerial Summary: This research points to the pivotal role of external representations, especially visuals, in strategic decision-making. Drawing from cognitive science, this study identifies four critical cognitive functions that benefit from these external representations—working memory, long-term memory, pattern recognition, and knowledge transfer. Further, the study highlights that external representations significantly influence the process of strategic decision-making in predictable ways. Finally, we show that not all external representations are alike in their ease of use and a managers' ability to operate on an external representation, referred to as representational capability, greatly affects the decision-making quality. The implications extend to users, designers, and educators of external representations, urging attention to the design and use of external representations for improved decision outcomes.

KEYWORDS

boundedly rational search, external representation, problem space, strategic decision-making, visuals

"Solving a problem simply means representing it so as to make the solution transparent."

—Simon (1996, p. 132)

1 | INTRODUCTION

1.1 | Strategy and external representations

External representations—typically in the form of visuals—are a pervasive component of how strategy is taught and practiced. For instance, key concepts traditionally taught in the MBA classroom: the quality–price frontier, the "five forces," the value "wedge," and both firm and industry value chains are all virtually inseparable from their visual representation. Likewise, many recent practitioner-oriented strategy concepts are essentially visual representations; examples include Kaplan and Norton's (2004) strategy maps, Kim and Mauborgne's (2005) strategy canvas, and Osterwalder et al.'s (2010) business model canvas. That most strategy concepts have a visual representation has motivated initiatives dedicated to summarizing strategy in terms of those representations. For instance, Krogerus and Tschäppeler (2012) summarize strategy in terms of 50 visual representations; McKeown (2012), Bryson et al. (2014), Birkinshaw and Mark (2015), and Van den Berg and Pietersma (2015) have published work along similar lines.

Additional support for the pervasiveness of these representations in strategy comes from strategy consulting projects, the most common output of which are presentations replete with

TABLE 1 Types of visuals used by books in various business fields (%).

Field	Diagrams	Graphs	Pictures	Verbal tables	Numerical tables
Strategy	64.1	2.6	11.8	20.3	1.2
Operations	34.4	22.4	18.2	12.8	12.3
Marketing	31.4	10.8	34.4	17.3	6.2
Accounting	12.7	5.0	3.5	8.3	70.4
Finance	10.7	44.7	0.9	13.6	30.2

visual aids (Kaplan, 2011; Raisel, 1999, p. 105). This pervasiveness may explain why many strategy terms have visual origins. Examples of such terms in the strategy literature are foresight, position, landscape, and vision (as in "the vision of the firm"). Strategy terms with visual origins are also frequent in practitioner-oriented discourse, as when a strategist is described as a "visionary" who "paints a fuller picture" of the firm's problems, "illuminates" the way forward, and offers a new "perspective" on the firm's "big picture."

In comparison to other fields, strategy not only uses external representations pervasively but also peculiarly. Examining the types of external representations used by different business fields reveals that strategy differs markedly from other fields in terms of the types of representations it uses. Table 1 illustrates this point by comparing different business fields' textbooks in terms of the percentage of their graphical content devoted to different types of visuals (for the methodology used to create this table, see Appendix A). For instance, whereas strategy relies more on diagrams (such as the industry value chain) and on "verbal tables" (e.g., listings of pros and cons); marketing relies more on pictures (e.g., advertising photography); accounting requires numerical tables (e.g., balance sheets and income statements); and finance depends on graphs (e.g., that plot data on stock returns). This suggests that external representations play a different role in strategy than in other business fields and, hence, understanding the role of external representations in strategy requires paying attention to the particulars of how these representations are used in strategy.

The pervasiveness and particular usage of external representations in strategy raises two questions: (1) *why* are external representations used so extensively in strategy? and (2) *how* do external representations affect the strategic decision-making (SDM) process?

1.2 | Our approach and contribution

To tackle these questions, we build on cognitive science research that has examined the role played by external representations in cognitive processes (Card, 2012; Cheng et al., 2001). An *external representation* is a physical artifact that can be used to maintain, display, or operate upon information about a problem (Norman, 1991, p. 17). Examples of external representations include written calculations, maps, diagrams, graphs, and architectural models (see Friendly, 2008 for more examples). Written texts, like this article or a memorandum, are also external representations; however, we will pay less attention to them here because their role in strategy is not different from in other fields.[1]

[1]A written text is typically the final outcome of a process that used several external representations (Sharples & Pemberton, 1992). It primarily serves more as a repository of information rather than as an artifact that can be used to operate upon information (Butcher, 2006). However, it is that latter function the one that is central in the SDM process (Csaszar, 2018b).

Figure 1 illustrates common external representations used in strategy. Because the vast majority of external representations that are specific to strategy are two-dimensional visual representations, they are sometimes referred to as "visual representations" or simply "visuals."[2]

While classical research on cognitive science assumed that cognition happened within the mind, the research on external representations has shown that much of cognition happens in conjunction with external artifacts. The key idea of the research on external representations is that without access to external artifacts, many cognitive processes would not happen or happen differently—or as Zhang (1997, p. 180) says, "external representations are not simply inputs and stimuli to the internal mind; rather, they are so intrinsic to many cognitive tasks that they guide, constrain, and even determine cognitive behavior." For instance, moving effectively in a large city without a map may be difficult and solving even basic mathematical problems without pen and paper may be impossible (Norman, 1991; Plumert & Spencer, 2007, p. 220). By showing that part of cognition is done outside of the mind, the research on external representations implies that an accurate understanding of cognition requires acknowledging the interactions between internal and external representations.[3]

Armed with ideas from the literature on external representation in cognitive science, we address the "why" and "how" questions that motivate our paper. We address the question of *why* external representations are used so extensively in strategy by identifying the challenges of the SDM process that are ameliorated by using external representations. Here, we build on multiple literatures, including cognitive representation (e.g., Newell & Simon, 1972; Thagard, 2005), visual processing (e.g., Card, 2012; Kosslyn, 1989), and boundary objects (e.g., Carlile, 2002; Star & Griesemer, 1989) to identify SDM challenges that are ameliorated by using external representations.

We address the question of *how* do external representations affect SDM by developing a conceptual model that extends the canonical understanding of boundedly rational search (Levinthal, 1997; Simon, 1955) to account for the interconnected nature of cognition, external representations, and search. Our conceptual model proposes that the quality of SDM, defined as the probability of identifying a satisficing solution,[4] depends on the interplay among the task environment difficulty, the managers' "representational capability," and the external representation's usability and malleability. We state the relationships involved in the form of five

[2]We sometimes use these terms when referring to two-dimensional external representations, but in line with cognitive psychology (Fox, 2020), we usually prefer the term "external representation," as this is more general and can account for three-dimensional, physical representations sometimes used in strategy such as Lego Serious Play (Kristiansen & Rasmussen, 2014) and prototypes (Hargadon & Sutton, 1997). Although most representations in strategy are visual, exceptions include braille memoranda, tactile maps, and corporate songs that help maintain a culture (like IBM's "Ever Onward"; Computer History Museum, 2014). The term external representations can also account for future developments, as the two-dimensional nature of most current external representations in strategy may be a reflection of the technologies that have been available to strategists. Therefore, new technologies like augmented reality and artificial intelligence may spur the creation of new external representations in strategy that go beyond two dimensions.

[3]The literature on external representations emphasizes that cognition extends beyond individual minds, expanding the concept of "cognition" to encompass interactions between individuals and artifacts. This perspective promotes the idea of "the extended mind" (Clark & Chalmers, 1998, p. 8; Paul, 2021; Zhang & Norman, 1994, p. 88) over the traditional understanding of cognition as a purely internal process.

[4]Our definition is consistent with Simon's (1955) characterization of the goal of decision making as finding a satisficing solution. Rather than focusing on the exact quality of a given decision, we are interested in the probability that a given decision-making process will lead to a desirable outcome. In terms of the landscape analogy, we develop later (Figure 4), we are interested in the probability of reaching a point that is above the "water level" rather than exact height of that point. Defining our dependent variable in this manner allows us to compare performance across different external representations.

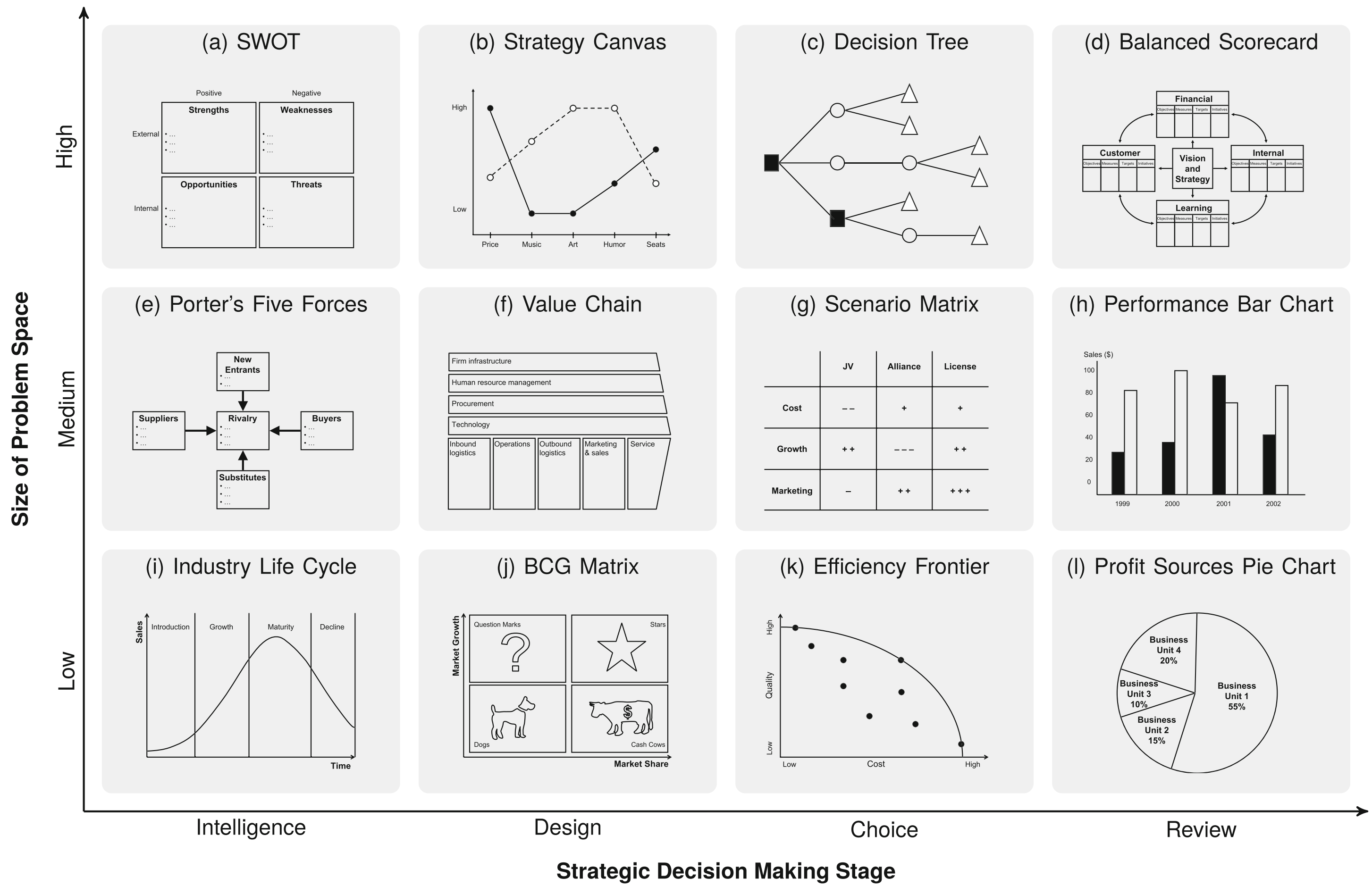

FIGURE 1 Examples of external representations in the field of strategy. This figure shows adaptations of the following external representations (early sources in parentheses): (a) SWOT analysis (Stewart et al., 1965); (b) Strategy Canvas (Kim & Mauborgne, 2005); (c) Decision trees (Raiffa, 1968); (d) Balanced Scorecard (Kaplan & Norton, 1996); (e) Porter's Five Forces (Porter, 1979); (f) Value Chain (Porter, 1980); (g) Scenario matrix (Franklin, 1772); (h) Performance Bar Chart (Playfair, 1801); (i) Industry Life Cycle (Vernon, 1966); (j) BCG matrix (Stalk & Hout, 1990, p. 12); (k) Efficiency Frontier (Markowitz, 1952); and (l) Pie Chart (Playfair, 1801).

testable propositions. These propositions imply, inter alia, that manager's representational capability has a paramount effect on search outcomes and that an external representation's malleability should have appropriate fit with the manager and the task environment. Our model yields practical recommendations for the users, designers, and teachers of external representations in strategy.

In addressing these why and how questions, we elaborate the nuanced pathways connecting internal and external representations (i.e., cognition and visuals). Answering why visuals are pervasive hinges on understanding the visuals → cognition pathway; in turn, answering how visuals affect the SDM process, hinges on understanding the cognition → visuals → cognition pathway (as we will explain later, here cognition first refers to representational capability and then search).

More generally, our paper contributes to the strategy and organizations literatures by furthering our understanding of the concept of external representations, an important yet understudied type of information processing within firms (Csaszar, 2018b, p. 616; Levinthal, 2011, p. 1520). Information processing within firms has been customarily studied in terms of two types of representations (Joseph & Gaba, 2020, p. 268): internal representations (i.e., individuals' representations) and distributed representations (i.e., groups' decision-making structures). However, research has paid less attention to the fact that much of the information processing by individuals and groups happens in conjunction with external representations. Fleshing out this type of information processing furthers the behavioral theory of the firm's main goal: to provide a realistic understanding of how organizations make decisions. It also addresses Gavetti, et al.'s (2007, p. 529) call to incorporate into this theory recent ideas from cognitive science.

1.3 | Relationship to other literatures

While cognitive science research on external representations can be traced back at least to Larkin and Simon (1987, p. 66) and has been steadily growing since then (see Belenky & Schalk, 2014 for an overview), the strategy field has almost not drawn from this body of research. However, two research streams in the strategy and organizations literatures—strategy tools-in-use (Jarzabkowski & Kaplan, 2015) and boundary objects (Carlile, 2002)—have paid attention to external representations, albeit using different theoretical lenses and focusing on different mechanisms and outcomes. Understanding how our work relates to these other research streams allows for better appreciating what is distinct about our contribution and how it complements these other approaches.

The research on strategy tools-in-use examines how external representations can be used for goals other than making good decisions (Jarzabkowski & Kaplan, 2015, p. 541), such as influencing peers and superiors (Mantere & Vaara, 2008), portraying the firm in a positive light (Grant, 2003), signaling status and skill (McKenna, 2010), gaining support (Kaplan, 2008), and resolving political conflicts (Eisenhardt & Bourgeois, 1988). This research casts a “sociological eye” on external representations (Whittington, 2007). In contrast, our focus is on how external representations affect the ability to make good decisions (the dependent variable of our conceptual model is the quality of SDM) and we examine external representations from a cognitive perspective—through a “cognitive eye.” Thus, we complement the research on strategy tools-in-use in terms of both mechanisms and outcomes.

The research on boundary objects focuses on how external representations facilitate shared understanding between different groups (Carlile, 2002). Important themes in this literature include how boundary objects underlie phenomena such as creation of shared meaning (Okhuysen & Bechky, 2009; Thompson, 2005), coordination of efforts (Carlile, 2002; Nicolini et al., 2012), and development of new products by cross-functional teams (Bechky, 2003; Seidel & O'Mahony, 2014). This research studies the communication effects of external representations—it casts a "communicational eye" on external representations.[5] Our research differs from the research on boundary objects in the explanatory mechanisms used—cognitive processes rather than communicational processes—and in the main outcome variable used—decision-making quality rather than communication and coordination. As we will explain later, our research also builds on and augments the boundary objects literature because some of the cognitive mechanisms we examine either affect communication or are affected by it.

In sum, previous management research has developed keen insights on external representations by looking at them through sociological and communicational perspectives—our research complements these literatures by taking a cognitive perspective. Moreover, our aim is to shed light on how external representations affect decision-making. Paying attention to the role played by external representations in strategy is important, as modern cognitive science points out that external representations play a central role in cognition, yet the cognitive models used in strategy for the most part overlook external representations. Thus, a fuller understanding of the role of external representations in strategy can enhance the psychological realism of strategy research and potentially enhance the value derived by creators and users of such representations.

2 | WHY ARE EXTERNAL REPRESENTATIONS PERVASIVE IN STRATEGY?

To answer this question, we first describe the challenges inherent to strategy problems. We then describe the role of representations in the context of strategy and show how external representations help surmount those challenges. Because our theorizing builds on a variety of research, and some of it may be unfamiliar to strategy scholars, Table 2 provides a glossary of the key terms used throughout the paper.

2.1 | Why strategy problems are challenging

Strategy problems feature several attributes that create difficulties for managers. First, such problems generally involve high stakes (Bourgeois, 1985; Eisenhardt & Bourgeois, 1988; Mintzberg et al., 1976, p. 246) and can even determine a firm's survival (Eisenhardt & Zbaracki, 1992, p. 17). Second, strategy problems are hard to formulate and solve. Formulating them is complicated because strategy problems are often unstructured and ambiguous (Schwenk, 1988), and solving them is complicated by their typically novel, uncertain, and complex nature—that is, strategy problems tend to have multiple parts and interactions (Leiblein et al., 2018; Rivkin, 2000; Simon, 1962). Strategy problems exemplify "wicked problems," where learning is a challenge because feedback is delayed and also noisy (Churchman, 1967; Hogarth et al., 2015). These characteristics can easily overwhelm the bounded cognitive resources of managers (Schwenk, 1984; Simon, 1955).

[5]In fact, the seminal paper on boundary objects, Star (1989), proposed this concept as a mechanism for allowing different artificial intelligences to communicate.

TABLE 2 Glossary of key terminology and definitions used in the paper.

Term	Definition
Representation	A model that can be used to generate predictions (Craik, 1943, p. 61).
Internal representation	A representation held inside an individual's mind (Craik, 1943, p. 61; Csaszar, 2018b, p. 607).
External representation	A physical artifact that can be used to maintain, display, or operate upon information about a problem (Norman, 1991, p. 17).
Framework	A suggested representation of a class of strategy problems, akin to an "expert system" that suggests prescriptions once fed with information (Porter, 1991, p. 98).
Externalization	The process of transforming tacit knowledge into explicit knowledge (Nonaka, 1994, p. 19).
Internalization	The process of transforming explicit knowledge into tacit knowledge (Nonaka, 1994, p. 19).
Task environment	The actual problem faced by a decision maker (Newell & Simon, 1972, p. 151).
Problem space	The set of possible configurations that a decision maker might consider for a given problem (Ohlsson, 2012, p. 106).
Problem space size	The number of possible configurations in the problem space (Levinthal, 1997, p. 936).
Problem space satisfiability	The share of all possible configurations that meet the manager's threshold of acceptance.
Search effort	How many configurations a manager tries before stopping the search (Csaszar & Levinthal, 2016).
Representational capability	A manager's ability to select an external representation that fits the problem well, populate it with adequate information, and monitor its effectiveness.
Usability	The extent to which helpful information can be extracted from an external representation (Kosslyn, 1989).
Pre-attentive processing	The detection of patterns from a visual without requiring conscious attention (Ware, 2013, p. 152).
Malleability	The extent to which an external representation can be changed by those using it (Anderson, 1984, pp. 27–28).

2.2 | The role of representations in addressing strategy problems

Managers are required to deal with strategy problems despite their challenging nature. They do so by using a representation of the strategic problem: a small-scale model that can be used to generate predictions (Craik, 1943; Holland et al., 1986). In fact, the fundamental premise of the Carnegie tradition is that managers are boundedly rational and therefore make decisions based not on the real problem but rather on an incomplete and thus inaccurate representation of it (Simon, 1955, p. 101).

Because the essence of a strategist's job is to deal with challenging problems, much work in the field of strategy amounts to studying representations that managers can use to enable good decision-making. Most research that deals explicitly with representations in strategy focuses on the *internal* (i.e., mental) representations of managers—in other words, representations that are held inside managers' minds (Csaszar, 2018b, p. 607). This line of research has demonstrated considerable heterogeneity among managers' representations, including differences in how they represent competitors (Porac et al., 1989), employees (DeNisi et al., 1984), product features (Benner & Tripsas, 2012), market uncertainty (Milliken, 1990), technological opportunities (Eggers & Kaplan, 2009), and power relationships (Krackhardt, 1990).

Given that developing an internal representation for a given strategic problem is challenging, academics and consultants offer *suggested representations* for specific classes of problems. These suggested representations are known as *frameworks*. Porter (1991, p. 98) explains that frameworks are akin to "expert systems" in that they suggest prescriptions once they are fed with information about a problem. Frameworks attempt to capture the complexity of real problems and can be tailored to different businesses. Porter contrasts frameworks with the stylized models commonly used in academic research (such as regression models and formal models), which are not typically as prescriptive and general.

Because frameworks are suggested representations, they are not bound by the same constraints as actual, "in use" internal or external representations. In particular, frameworks can be more complex than what an actual cognitive process can manage. For instance, Porter's Five Forces framework takes about nine pages of text to describe (Porter, 1979). Porter's framework, thus, is all the ideas described in those pages. In contrast, the commonly used external representation of the Five Forces (see Figure 1e), is a concise visual that fits on one page and displays only some of the key elements of the framework. For example, the myriad mechanisms that Porter (1979) describes as driving each force are not part of the visual representation. Taking inspiration from Porter's (1991) analogy, if a framework is akin to an expert system—a sophisticated software—then the visual representation of a framework is akin to the expert system's graphical user interface. The focus of this article is these visual external representations rather than the underlying frameworks.

As previously mentioned, the cognitive science literature has made a strong case that many of the representations that humans use when solving problems are external representations (Clark & Chalmers, 1998; Kirsh, 2010).[6] This is especially true for complex problems. For instance, most people can solve simple arithmetic problems in their head but require writing down calculations for more complicated problems (Múñez et al., 2013); similarly, small architectural changes can be imagined but new buildings are thought out using external representations such as 3D models (Rahimian & Ibrahim, 2011). The prevalence of external representations in strategy is consistent with the challenging nature of strategy problems—managers with their internal representations alone are ill-equipped to deal with the complexity of strategy problems. The little attention that strategy research has paid to external representations is perplexing, given their prevalence in strategy practice and the strong support for them in cognitive science.

2.3 | How external representations mitigate the challenges posed by strategy problems

To achieve a better understanding of why external representations are so prevalent in strategy, we now focus on the specific cognitive functions of strategists that are helped by external representations. In particular, we show that external representations, typically in the form of visual

[6]See Csaszar (2018b) for a more detailed discussion of the different types of representations, including distributed representations.

representations, help managers deal with strategy's complex problems by improving four cognitive functions—working memory, long-term memory, pattern recognition, and knowledge transfer and transformation—that are central to solving strategy problems.

All the mechanisms that we shall discuss operate by harnessing the human visual system[7] to perform tasks that are useful in the context of strategy problems, thereby making it possible to substantially increase the processing power and "bandwidth" that can be brought to bear on such problems. Indeed, the visual system accounts for about a third of the human cerebral cortex (Van Essen, 2004, p. 7), and humans acquire more information through that system than through all other senses combined (Ware, 2013, p. 2). Thus, external representations expand individuals' cognitive capacities, which is especially valuable when dealing with complex problems such as those faced by strategists. A famous historical example of external representations helping to solve complex problems is that the group of researchers who discovered the structure of DNA used visuals (in the form of X-ray images and physical three-dimensional models) to a much greater extent than did their competitors, who did not consider visuals to be a serious approach to science (Watson, 1968, p. 212). Another example of the importance of external representations in SDM is how NASA scientists' reliance on an incomplete graphical plot of temperatures and engine failures misled them to move forward with the Challenger launch, whereas a correct graph would have revealed the truth at a glance and averted the infamous disaster (Vaughan, 1996, p. 383).[8] In short, we propose that external representations are preeminent in strategy because they have the potential to allow managers to tap into otherwise dormant cognitive resources that are critical for solving strategy problems.

In what follows, we describe in more detail the four cognitive functions that are improved by using external representations. To make the discussion more concrete, we will refer to some specific examples of visuals used in strategy. Each of these examples appears as a panel in Figure 1, which illustrates 12 of the most common visuals used in strategy.[9] The figure is organized along two dimensions: the SDM stage normally addressed by the visual (the x-axis) and the size of the problem space that it generates (the y-axis); the latter dimension will play a prominent role in later sections.

2.3.1 | Offloading and expanding working memory

Humans have a limited capacity to keep multiple items in their working memory: 7 ± 2 items according to Miller's (1956) dictum or perhaps only 4 ± 1 according to more recent research (McCollough et al., 2007). It follows that keeping in mind the multiple dimensions of a strategy problem, as well as their possible values and interactions, is not humanly possible except in the simplest cases.

[7]This system, which facilitates perception of the physical world, encompasses both the detection and processing of visual information (Ware, 2013, p. 2).

[8]Additional support for the idea that external representations help managers tackle complex problems has been provided in multiple domains, such as accounting (Taffler & Smith, 1996), chemistry (Bodner & Domin, 2000), marketing (Edell & Staelin, 1983), medical diagnosis (Rogers & Arkin, 1991), and product design (Goldschmidt & Smolkov, 2006).

[9]The external representations in Figure 1 were derived from our analysis of 100 strategy textbooks and trade books published over the last 30 years. The archetypes selected are representative of the most common visuals used in a given strategic decision-making stage (Lipshitz & Bar-Ilan, 1996; Simon, 1977, p. 41) and are also clustered according to the size of the problem space they generate (Simon & Newell, 1971, pp. 93–94).

External representations help managers deal with complex problems by freeing up working memory (Larkin, 1989; Herbert A. Simon, 1978). Employing an external representation while solving a problem is analogous to expanding a computer's random-access memory so that it can handle, say, larger spreadsheets that yield more accurate financial estimates. For example, spelling out the pros and cons of alternative scenarios—as in Figure 1g—enables one to consider the relevance of a given scenario characteristic, to compare multiple scenarios in terms of a single characteristic, and/or to tally the pros and cons of different scenarios. Attempting any of these extra analyses *without* the aid of an external representation, however, would likely result in errors due to the limits of human working memory. That external representations help overcome working memory limitations has been well documented in the context of visual programming languages, such as LabVIEW and Squeak, that enable programming via diagrams instead of plain text (see, e.g., Blackwell et al., 2001).

In sum, by freeing up a manager's working memory, the use of external representations allows for different ways of considering the strategic problem, increasing the chances of describing the problem in more relevant ways. Alternatively, one can keep the representation fixed and use the freed-up working memory for purposes such as managing and improving communications. For instance, the increased working memory could be used for articulating ideas in easy-to-understand terms or decoding nonverbal cues.

2.3.2 | Boosting long-term memory

Given that strategy problems are multi-dimensional, a practical challenge encountered by managers is remembering *which* dimensions should be considered. External representations can help managers recall those dimensions by serving as mnemonic devices. For instance, the SWOT analysis illustrated in Figure 1a is usually encapsulated as a 2×2 grid in which the columns are "positive" and "negative," and the rows are "internal" and "external." This structure makes it easy to recall the information that needs to be collected: strengths (information that is internal to the firm and positive), weaknesses (internal and negative), opportunities (external and positive), and threats (external and negative).

There are two reasons why external representations aid the recall of information. First, humans are much better at remembering visualizations than at remembering abstract ideas or verbal arguments of similar complexity (Kosslyn, 1980; Paivio & Csapo, 1973). In fact, most methods that aim to increase memorization ability are based on translating nonvisual information into visual information (Yates, 1966). Second, visuals add a relational context that describes the interconnection between the parts (Lurie & Mason, 2007, p. 161). This contextualization helps managers recall the visual's components as well as the connections among them.

2.3.3 | Enhancing the ability to recognize patterns

External representations, specifically visuals, also help humans recognize patterns and make inferences. For instance, although panels (a) and (b) in Figure 2 represent the same information, it is much easier to recognize that the three points lie on a straight line by looking at the graph in panel (b) than at the table in panel (a). A manager can similarly detect temporal and regional sales patterns more easily in a bar chart, like the one in Figure 1h, than in a table that contains the same information.

(a) Table

x	y
1.49	2.67
4.02	4.31
6.55	5.96

(b) Graph

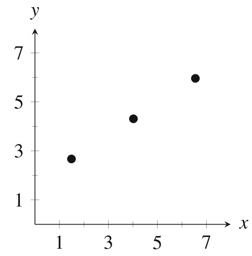

FIGURE 2 Different representations make different information accessible.

Larkin and Simon (1987, p. 92) call the detection of such visual patterns "zero-cost inferences" because they do not require conscious effort (e.g., it is immediately apparent when three points lie on a straight line). From an information processing viewpoint, these rapid inferences are possible because the brain analyzes visual information in parallel whereas verbal or numerical information is analyzed sequentially (Kauffman, 1985). Antonietti (1991) argues that the brain evolved the capacity to make fast inferences from visual data because doing so was necessary for survival. In a nutshell, representing a problem visually allows managers to co-opt the brain's fast and sophisticated pattern recognition abilities.

2.3.4 | Improving knowledge transfer and transformation

Unlike the three previously discussed cognitive functions that are helped by external representations (working memory, long-term memory, pattern recognition), the current and last function we examine—knowledge transfer and transformation—is not simply a cognitive function happening within an individual, but it involves multiple individuals and hence affects the group's *distributed* cognition (Csaszar & Steinberger, 2022, pp. 19–20). Here, phenomena such as communication, coordination, and conflict become center stage.

External representations help the transfer of knowledge because they underlie two key processes necessary for knowledge transfer: externalization and internalization of knowledge (respectively, turning tacit into explicit knowledge and vice versa; Nonaka, 1994, p. 19). External representations aid externalization by providing succinct and flexible ways to express previously tacit knowledge (Norman, 1991, pp. 43–46). For example, consultants can more easily externalize their knowledge about an organization's structure by drawing an organizational chart than by describing that structure in text. External representations aid internalization, too, since they offer an efficient way to absorb complex information (Bocanegra et al., 2019, p. 136); after all (as the adage says), "a picture is worth a thousand words." In the context of strategy, external representations' ability to transfer knowledge can be used to communicate a strategy, which is particularly useful during strategy implementation. It is also useful when learning strategy (as when MBAs take strategy courses), as external representations accelerate the learning of different representations vis-à-vis solely relying on theory and case-based lectures (Rau et al., 2015; Schnotz, 2002).

Oftentimes, strategy does not just require transferring knowledge from one individual to another but transforming it to create new knowledge. This is the case when the information necessary to develop a good strategy is dispersed among multiple individuals and finding a solution requires co-creating it. Such situations have been extensively studied by the boundary objects literature (Star & Griesemer, 1989). This literature has demonstrated that external representations facilitate the creation of a shared understanding, as external representations allow the different parties to more easily understand others and imagine how the different perspectives may fit together (Carlile, 2002). The use of external representations is especially helpful to bridge functional, hierarchical, or cultural boundaries (Nicolini et al., 2012; Wright et al., 2013). Bechky (2003) shows that using external representations makes group misunderstandings more visible, which prompts the creation of common ground and a richer understanding of the problem. This process is facilitated by the ease with which visuals can be modified, which allows to quickly try different understandings—a process referred to as "bootstrapping" by Nersessian (2008, p. 184). Progressively developing a shared understanding is arguably the main reason why external representations are the preferred tool of "design thinking," which seeks to leverage the ability of groups to find viable solutions rapidly (Fraser, 2012). In the context of strategy, transforming the knowledge of multiple individuals into a richer understanding is particularly valuable during strategy formulation (Baer et al., 2013).

Finally, it is important to note the role of conflict in the context of knowledge transfer and transformation. Because not all actors engaged in the SDM process may have the same preferences and information, SDM is fertile ground for conflict (Eisenhardt & Bourgeois, 1988). Conflict is more likely to emerge when environmental ambiguity and group differences are extreme; in such situations, boundary objects may not be enough to help the group converge to a shared understanding (Zuzul, 2019). In the presence of conflict, external representations can allow a focal individual to persuade others about the merits of a particular path of action (Barley, 2015; Jarzabkowski & Kaplan, 2015). For instance, Kaplan (2011) depicts the political struggles associated with who had control over a project's external representations (embodied as the project's PowerPoints) and shows that those in control of the external representations used their power to determine the project's scope and direction by including or excluding certain ideas and participants.

In sum, external representations facilitate knowledge transfer and transformation in multiple ways: by enabling internalization and externalization of knowledge, by serving as boundary objects and aiding co-creation, and by granting power to persuade others.

We are now in a position to answer the question motivating this section: external representations pervade strategy because they enhance the capacity of managers to deal with a strategy problem by improving cognitive functions that are essential to SDM (working memory, long-term memory, pattern recognition, and knowledge transfer and transformation).

3 | SDM: THE BASELINE MODEL

We now move on to exploring *how* external representations affect SDM. We will answer this question in terms of the conceptual model outlined in Figure 3. Read from right-to-left, this figure describes how the quality of SDM depends on: characteristics of the problem (the difficulty of the task environment as well as the size and satisfiability of the problem space), characteristics of the managers (their representational capability), and characteristics of the external representations used (their usability and malleability). Several of these elements affect each other nontrivially, with managers' representational capability playing a central role in moderating many of the effects.

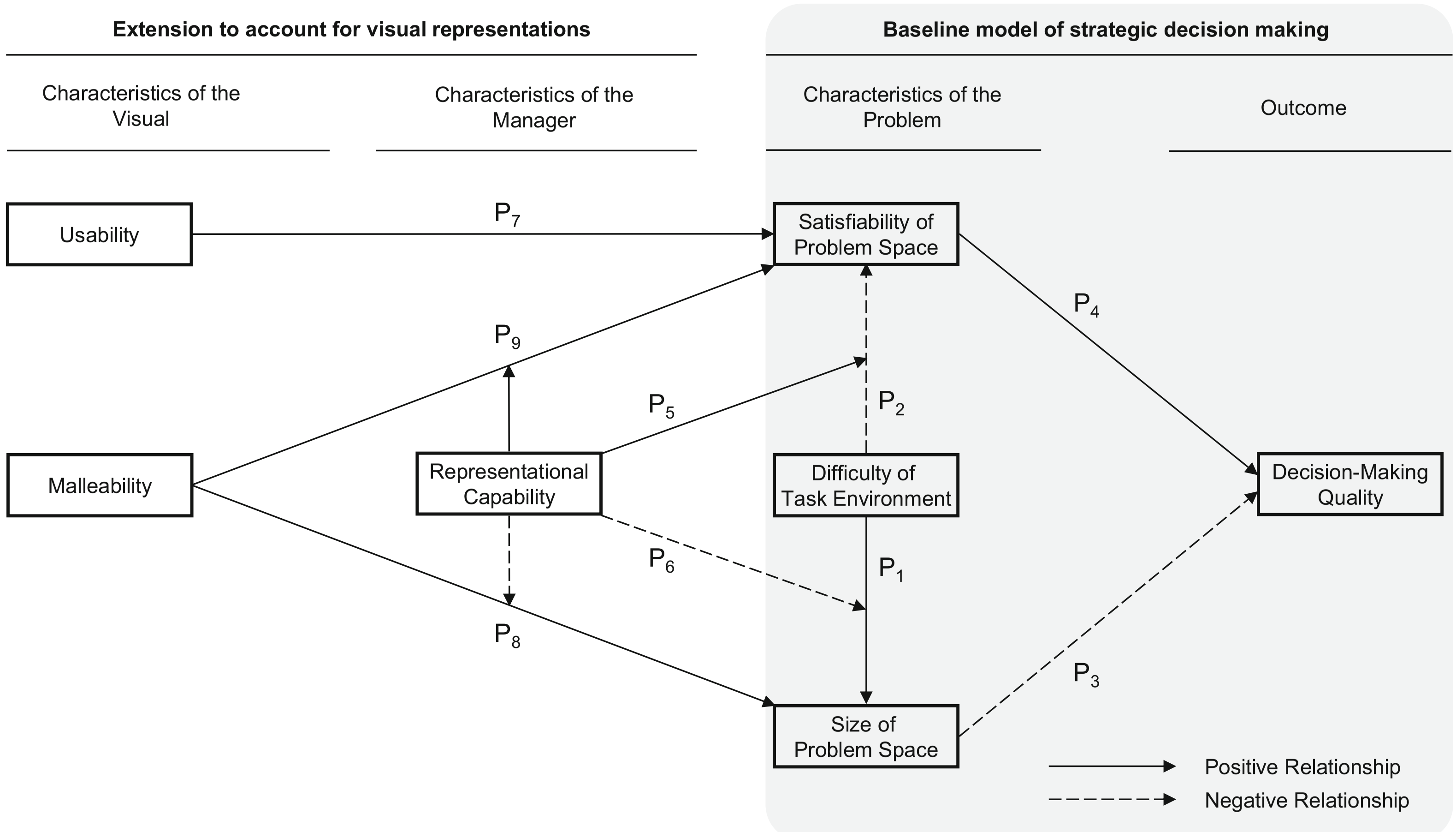

FIGURE 3 Factors that influence the effect of external representations on decision-making quality.

We shall describe the model in two steps. In this section, we present a baseline model that describes central elements of how strategy conceptualizes the search process; this description corresponds to the right-hand (shaded) part of Figure 3 and it is based on classic research on problem solving and search (Levinthal, 1997; Newell & Simon, 1972). In the next section, we augment the baseline model to capture the effect of external representations—an exercise that corresponds to Figure 3 left-hand part. Our extension of the baseline model builds on newer research from cognitive science on the role of visuals in decision-making (e.g., Kirsh, 2010; Ware, 2013). We connect the figure to the text by associating each numbered proposition to a corresponding arrow (P_1–P_5) in Figure 3.

The baseline model focuses on how characteristics of the strategic problem faced by the firm ultimately affect the quality of decision-making. Specifically, we combine Newell and Simon's (1972) conceptualization of a decision maker's task environment and problem space with Levinthal's (1997) conceptualization of decision-making as search on a rugged landscape.

The primary outcome of the SDM process is the quality of decisions (Eisenhardt & Zbaracki, 1992; Mintzberg et al., 1976). Consistent with this, the dependent variable of our model is decision-making quality. It is worth noting that this dependent variable measures the quality of a process rather than the quality of a specific decision. The distinction is important, as we are ultimately interested in comparing the performance of different processes (i.e., searching under different external representations).

We define decision-making quality as the probability that the decision process achieves a desired aspiration level.[10] In terms of the landscape imagery (Levinthal, 1997), the quality of a decision-making process is the probability that after a process of search, the firm ends up at a point that is above its aspiration level. This contrasts with the quality of a given decision, which corresponds to the height of a given position in the landscape.

Decision-making quality depends on the *size* and *satisfiability* of the problem space. The problem space is the set of possible configurations that a decision maker might consider for a given problem (Ohlsson, 2012, p. 106).

The *size* of the problem space refers to its cardinality; that is, the number of possible configurations or alternatives that decision makers can select from in a given problem space. For example, if an automobile company is addressing a problem space that comprises the dimensions of speed, color, and price and if each of those dimensions can take one of two possible values (e.g., slow or fast, red or blue, and cheap or expensive), then the problem space has $2^3 = 8$ possible configurations. The size of the problem space grows exponentially as the number of dimensions and of values per dimension increase. It is for this reason that external representations, like SWOT analysis or the strategy canvas, which are open-ended, produce problem spaces that are much larger than external representations that only allow for a definite set of dimensions and values per dimension, such as the industry life cycle and the BCG matrix (for more comparisons of this sort, compare the external representations in the different "rows" of Figure 1).

Satisfiability refers to the share of all possible configurations that actually meet the manager's threshold of acceptance; this notion, which is sometimes termed *satisficing* (to distinguish it from the stronger approval implied by *satisfying*), depends on the manager's aspiration level and also on the task environment's difficulty. Suppose, for example, that only two of the eight

[10]Cyert and March (1963, p. 10) and ensuing works (e.g., Kahneman & Tversky, 1979; March & Shapira, 1992) define "aspiration level" as a minimum level of performance that an individual or organization considers satisfactory. The aspiration level dichotomizes outcomes, producing a "utility function with essentially two values—good enough and not good enough" (Cyert & March, 1963, p. 10).

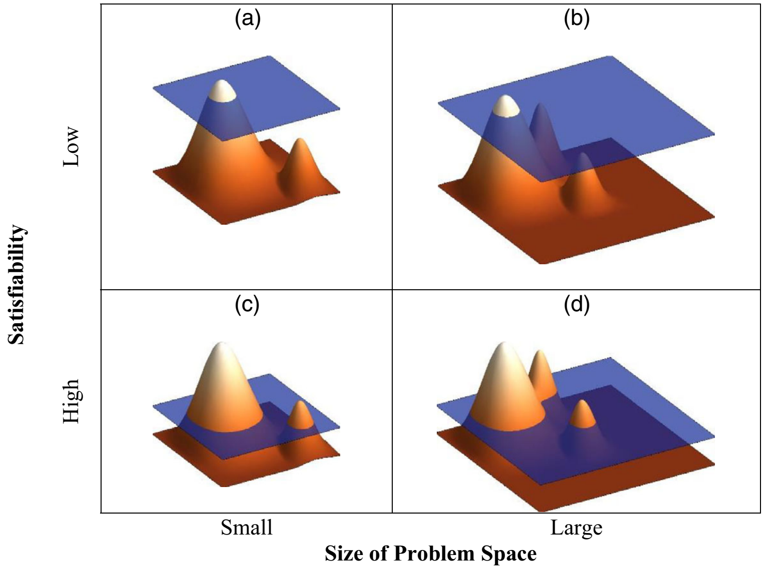

FIGURE 4 Landscapes with different problem size (columns) and satisfiability (rows); a low satisfiability corresponds to a high "water level".

previously described automobile configurations would generate sufficient profit for the car company. In that event, the satisfiability would be equal to 25%.

In terms of the fitness landscape imagery, size refers to how large the landscape is, while satisfiability is the proportion of positions that have heights exceeding a specific "water level" (see Figure 4). The landscape positions (defined by their x and y coordinates) represent the possible configurations, and the height of a position (the z coordinate associated with an (x, y) position) represents the fitness. Although configurations are usually described by more than two dimensions (e.g., a car's speed, color, and price), high-dimensional landscapes are difficult to visualize. Visualizing landscapes as the two-dimensional surfaces in Figure 4, while not entirely precise, helps develop intuitions about their behavior (for more information on fitness landscapes and their visualization, see Csaszar, 2018a). In the landscape imagery, the size of the problem space corresponds to the size of the landscape. For example, if the x and y coordinates in panel (c) of Figure 4 range from 0 to 1, and those in panel (d) range from 0 to 2, the latter landscape is four times larger than the former.[11] A larger size means that firms must traverse greater distances to escape a low-quality "neighborhood" of the landscape. For instance, if a firm starts at the right corner of panel (d), it must "swim" nearly half the landscape to reach the small "island" in the middle of the "ocean." In contrast, a firm starting at the right corner of panel (c) would be much closer to reaching the nearest island.

The size of the problem space and the proportion of its positions that are satisficing, depend on the actual problem faced by a decision maker, or the *task environment* (Newell & Simon, 1972, p. 151). In Newell and Simon's (1972) classic study of how individuals play chess, for example, the task environment comprises the rules of the game and the current

[11]The larger range of each axis can be interpreted as more possible alternatives per dimension (e.g., picking from a larger spectrum of colors for the car) or—given the limitations of visualizing landscapes as two-dimensional surfaces—as representing the fact that a more complex task environment has more than two dimensions.

configuration of the board. Note that the problem space is a *representation* (i.e., a simple model) of the task environment. It is interesting that most of the search literature assumes the problem space is given and thus implicitly supposes that it adequately describes the task environment. Although these presuppositions may hold for extremely simple task environments, they will not hold in any of the real-world settings that a manager is likely to encounter (Csaszar, 2018b; Levinthal, 2011). It is for this reason that our extended conceptual model (presented in the next section) incorporates the role of representations.

Because a more difficult task environment contains more parts and/or parts that only fit in very specific ways, such environments generally entail larger problem spaces and lower satisfiability; conversely, less difficult task environments are associated with smaller problem spaces and higher satisfiability. Searching for a satisficing solution when facing a difficult task environment is akin to facing a needle-in-a-haystack landscape (Bruderer & Singh, 1996)—a landscape with few very narrow, needle-like peaks surrounded by a vast ocean. This sparsity of satisficing solutions makes the chance of finding one low. Simon's (1962, p. 470) classic story about watchmaking serves to exemplify these concepts. Watches with either more gears or with gears that interact more intricately are more difficult to assemble into a well-functioning watch. In sum, the increased difficulty of the task environment makes finding a satisficing solution more challenging. This is why playing chess is harder than playing tic-tac-toe (Allis, 1994, p. 6), and managing a multinational corporation is more challenging than managing a lemonade stand. In terms of baseline propositions:

Baseline proposition 1. *Higher task environment difficulty leads to a higher problem space size.*

Baseline proposition 2. *Higher task environment difficulty leads to lower satisfiability of the problem space.*

Managers search for a satisficing solution in the problem space. Note that the chances of finding such a solution not only depend on the satisfiability of the landscape but also on its size. High satisfiability increases the likelihood of a randomly chosen solution being good enough. At the same time, holding satisfiability constant, if the problem space is larger it is more likely there may be long stretches of the problem space that contain *no* good solutions. This is due to an increase in the number of steps required to go from one location in the problem space to another.[12] This implies that local search processes will require more trials before a good solution is found. Because time is typically limited (by, e.g., fast-paced competition and/or attentional constraints), a search that takes too long may be terminated before it finds a good solution.

Baseline proposition 3. *Higher problem space size leads to lower decision-making quality.*

Baseline proposition 4. *Higher satisfiability of the problem space leads to higher decision-making quality.*

[12]Or put differently: If 10% of a lake's area is occupied by islands, a swimmer who is randomly dropped somewhere on the water stands a better chance of reaching land in a smaller rather than a larger lake.

4 | AUGMENTING THE BASELINE MODEL WITH EXTERNAL REPRESENTATIONS

To study *how* external representations affect SDM, we now augment the baseline model to include the role of external representations. We do so by connecting the ideas about search developed in the previous section to ideas from cognitive science on the role of external representations (e.g., Kirsh, 2010; Ware, 2013; Zhang, 1997). This section introduces five testable hypotheses and completes the conceptual model started in the previous section and outlined in Figure 3. We structure this section as follows. First, we add representations to the baseline model. Second, we show that the quality of the selected representation depends on a "representational capability." Finally, we show how characteristics of external representations (their malleability and usability) affect different relationships within the model.

4.1 | Accounting for the role of representations on search

As mentioned previously, a critical assumption of the baseline model is that search occurs on a given problem space that is fixed. Such a model does not account for how that problem space is chosen or can be changed. Research into the role of representations in search (e.g., Csaszar & Levinthal, 2016) is a fairly recent development.

To add the role of representations to our conceptual model, we start by recalling that any representation of a task environment is a small-scale model (Craik, 1943, p. 61). The implications of this fact are: (i) that each representation can capture only a subset of a given task environment's dimensions and (ii) that there are multiple representations for any task environment. We now elaborate on how these implications affect the baseline model.

Since representations do not capture all of the problem's dimensions, it follows that choosing one representation must blind the manager to other problem dimensions. Blackwell, Whitley, Good, and Petre (2001, p. 102) put it this way: a "notation makes some information accessible at the expense of obscuring other information." For instance, if a problem is represented in terms of operational efficiency, then its proposed solution will probably not deal with targeting a new market segment; that solution would be problematic, of course, if the lion's share of potential profits were expected to come from new markets. So, when selecting a representation, managers count on the irrelevance of unconsidered dimensions. Yet if that faith is misplaced, then the representation chosen is unlikely to yield a good solution.

Second, the possibility of representing most problems in myriad ways explains why strategic decisions are complicated by competing analyses of the problem. Thus, for example, if a strategy's success depended on 20 different factors, then a total of 190 $\left(=\binom{20}{2}\right)$ different 2×2 frameworks could be used to represent the strategy space.

Among this multiplicity of representations, some will be superior to others in terms of making it easier to identify a satisficing solution (Kotovsky et al., 1985). The best representations capture the most relevant subset of dimensions while minimizing the size of the problem space (Hayes, 1989, pp. 25–26). Hence, a simple representation that highlights a relevant subset of dimensions is often preferable to a more "faithful" but complex representation—a point made in multiple literatures (see, e.g., Card, 2012, p. 521; Csaszar & Levinthal, 2016, p. 2042; Felin & Zenger, 2017, p. 268). Choosing a representation is challenging and consequential: there are myriad representations to choose from and which one is chosen considerably affects the alternatives the firm will consider. Because choosing a representation critically affects the chances of finding a good solution, Simon (1996, p. 132) only slightly exaggerated when saying that "solving a problem simply means representing it so as to make the solution transparent."

4.2 | Representational capability

Since finding a representation requires cognitive effort and since managers differ in their cognitive capabilities (Helfat & Peteraf, 2015), one can reasonably assume that some managers are better than others at selecting representations. When digital imaging emerged in the 1980s, for instance, managers at similar firms represented the problem quite differently: FujiFilm's managers realized that consumers would appreciate digital photography and rapidly developed its digital business, while Polaroid's managers thought otherwise and remained attached to the old technology (Tripsas & Gavetti, 2000). Another example is that of investment banker Charles Merrill, who correctly predicted that adding "supermarket" attributes to brokerage firms would lead to greater sales (Gavetti & Menon, 2016).

We use the term *representational capability* to refer to a manager's ability to use good external representations—external representations characterized by high satisfiability and a small problem space.[13] Managers who rank higher on this capability are better equipped to (i) select (and sometimes create) an external representation that fits the problem well, (ii) populate the external representation with adequate information, (iii) and track the effectiveness of the selected representation to avoid fixation.

Selecting and populating an external representation relies on a manager's identification of the structural features of the problem at hand (Gavetti et al., 2005, p. 695). Understanding this structure allows the manager to pick a representation that captures the key features of the problem and to determine what is the most relevant information that needs to be incorporated into the representation. If either of these—the external representation or the data—is off, the final decision is likely to be poor (in Section 5, we elaborate on causes and solutions to these problems).

Managers typically select among ready-made external representations (e.g., a manager deciding whether to present a market power problem in terms of the five forces or the strategy canvas). Yet sometimes the selected external representation is custom-made, created particularly for the occasion (e.g., a manager devising a new way of mapping the main competitors, perhaps based on industry-specific metrics). In such cases, the selection is not among external representations, but among the elements that will compose it (see Bertin, 1983; Tufte, 1983 for classic accounts on the process of creating new external representations such as diagrams, graphs, and maps). The creation of new external representations adds value when it provides a superior way of finding solutions than all existing external representations (i.e., for the same task environment, produce problem spaces that are easier to satisfice). For this reason, those with ample knowledge of existing external representations and problems—such as academics and consultants—are in a privileged position to create new external representations.

[13]We avoid referring to this capability as "external representational capability" given that, as explained earlier, even the simplest strategy problems are too complex for most managers to process internally (i.e., strategy problems overwhelm managers' working memory, long-term memory, pattern recognition ability, and their ability to transfer and transformation knowledge). Therefore, external representations are necessary except in the simplest (or most haphazard) strategic processes.

Tracking the effectiveness of an external representation depends on a manager's metacognition or self-monitoring of thought processes. Metacognition allows managers to determine when it is time to depart from an established representation and initiate a search for alternative representations (Bandura, 1991). If the effectiveness of a given representation is not monitored there is a risk of fixating on a weak representation (also referred to as Einstellung effect; Luchins, 1942). In sum, representational capability enables the adequate selection and population of an initial representation as well as the flexibility to switch between representations, which enables dislodging from local peaks in the search process (Csaszar & Siggelkow, 2010, p. 674). We summarize these considerations in our next two propositions.

Proposition 1. *All else equal, managers with higher representational capability generate problem spaces with higher satisfiability.*

Proposition 2. *All else equal, managers with higher representational capability generate problem spaces of smaller size.*

One question that naturally arises in this context is the *source* of representational capability. Previous research in strategy suggests that representational capability depends on managers' education and experience. For example, Dearborn and Simon (1958) report that managers with different functional expertise represent the same problem differently—as when profits are attributed to technical specifications by an engineer but to customer demographics by a marketing manager. Along the same lines, Dougherty (1992) and Benner and Tripsas (2012) document the effect of prior industry experience on the representations that managers develop. The effect of education and experience is typically measured in terms of "depth" and "breadth" (Gavetti et al., 2005, p. 697).

Because representational capability requires matching a strategic problem with an external representation, we conjecture that managers with high representational capability combine deep knowledge about the problem domain with high breadth regarding the available representations. That is, representational breadth gives managers a large repertoire of external representations from which to select a good representation, and problem-domain depth endows managers with detailed and accurate information with which to populate the chosen representation as well as the ability to keep monitoring whether the chosen representation continues to be appropriate.

4.3 | Accounting for characteristics of external representations: Usability and malleability

Decision-making quality is affected not only by aspects of the individual who is searching, as just described, but also by characteristics of external representation used. Because the primary focus of our study is the mostly visual, external representations that are specific to strategy, this section draws on the cognitive science literature on visual representations to examine characteristics unique to this type of external representation. This level of specificity is necessary, as the processing of visual representations depends on the hard-wired neural circuitry of the human visual system.

This literature has identified several characteristics that affect the use of visuals (for an overview of this research, see figure 1 in Bresciani, 2019 as well as Card, 2012). For the purposes of our paper, two of these characteristics stand out as particularly important to understand how visuals affect SDM: usability and malleability. We elaborate on these characteristics next.

4.3.1 | Usability

A visual representation's *usability* is the extent to which helpful information can be extracted from it (Kosslyn, 1989; Simon & Hayes, 1976). Unlike representational capability, which is a characteristic of managers, usability is a characteristic of the visual itself. Usability is perhaps most relevant to those who design visuals, such as consultants and academics who create frameworks and tools that are used by others.

Increasing a visual's usability increases a manager's likelihood of acquiring, processing, and correctly evaluating useful information (Jarvenpaa, 1990; Kleinmuntz & Schkade, 1993). Recall the example of Figure 2: if the goal is to spot a trend, then panel (b)'s graph is much more usable than panel (a)'s table *even though* the latter contains the same information. A classic example of usability is the map of cholera deaths in 1854 created by Dr. John Snow, which led to his conclusion that London's epidemic originated with the city's public water pumps (Tufte, 1983, p. 24). Although Dr. Robert Baker had access to similar data years earlier, he simply tabulated the total number of deaths per district—that is, without plotting the location of each death—and so was unable to infer the critical role played by those water pumps (Friendly, 2008, p. 27).

There is a vast literature on usability (see Johnson, 2014 and the references therein), but we shall be content to highlight a few ideas of greatest relevance to SDM. The usability of a visual depends strongly on the two mechanisms described next: pre-attentive processing and Gestalt principles. Designing a visual with these mechanisms in mind improves the odds that managers can use that representation to extract relevant information.

Pre-attentive processing occurs when a manager can detect patterns from a visual without requiring conscious attention (Ware, 2013, p. 152). We mentioned previously that Larkin and Simon (1987, p. 92) refer to such detection as "zero-cost inferences." A visual that reflects this feature practically ensures that a dimension so detectable will be considered by the decision maker. Pre-attentive processing is triggered by visual cues that distinguish one type of information from other types. A designer of visuals should therefore want a problem's most relevant aspects to be presented in such a way that this pre-attentive perception is activated. For a comprehensive description of pre-attentive features—which include form, color, position, and motion—see Ware (2013, pp. 152–60).

Gestalt principles aim to account for the visual system's behavior by explaining how ambiguities in visuals are resolved (Koffka, 1935). These principles can be used to facilitate pattern recognition (Chabris & Kosslyn, 2005, p. 40). There are seven well-established principles that are especially relevant to designing effective visuals for SDM (all seven principles are well described by Johnson, 2014, pp. 13–27). Although it is out of the scope for this article to detail how each principle affects visual processing, incorporating Gestalt principles into the design of visuals will increase a visual's usability, making it less likely that users will draw incorrect inferences from the representation.

A visual's usability is related also to the four cognitive functions identified in our discussion of *why* visuals are used in SDM. In particular, greater usability enhances managers' working and long-term memory, their identification of visual patterns, and the storage and transfer of knowledge.

In sum, visuals that are more usable increase the odds that the manager will retrieve valuable information and hence find a good solution. Formally, we have our next proposition as follows.

Proposition 3. *All else equal, the higher the usability of the visual, the higher the satisfiability of the problem space.*

From our definition of representational capability, it also follows that managers with higher representational capability should be more likely to select usable representations.[14] For example, if tasked with detecting patterns in data, such a manager would pick the graph rather than the table in Figure 2.

4.3.2 | Malleability

An external representation's *malleability* is the extent to which it can be changed by those using it (Anderson, 1984, pp. 27–28). In practice, this refers to how many of the dimensions captured by the external representation can be changed by the manager. Thus, the BCG matrix seen in Figure 1j, which always measures firms in terms of market share and market growth, is less malleable than the Scenario matrix in Figure 1g, which can include an unlimited number of pros and cons that may reflect any number of dimensions. In Figure 5, we arrange the 12 visuals of Figure 1 from the least to the most malleable.[15] Malleability is a key aspect of external representations because it affects the problem space's size and satisfiability in important and nontrivial ways.

Malleability has a double-edged effect on the size of the problem space. More specifically, whether the effect is positive or negative depends on the fit between the user and the problem. In the hands of a manager with high representational capability, malleability is helpful because the representation can be tailored to include the problem's most relevant dimensions. However, a manager with low representational capability will not know how best to tailor the external representation so that it captures the appropriate elements; such a manager is far less likely to discern the problem's deeper structural features (Gavetti et al., 2005) and may end up including many irrelevant dimensions.

Malleability also affects the satisfiability of the problem space. Following the same logic as before, we argue that malleability can either increase or decrease satisfiability depending on the manager's representational capability. In the hands of a skilled manager, malleability increases the chances of developing a representation that is efficient and effective, one that captures a limited number of essential dimensions, thereby making it more likely to yield satisficing solutions. For instance, an experienced consultant might propose a decision tree, as in Figure 1c, in which many of the end states are satisficing from the CEO's perspective. However, a manager

[14] We thank an anonymous reviewer for suggesting this point.

[15] The visuals in Figure 5 are arranged according to malleability, which can be roughly measured according to the number of dimensions that a manager can alter when using the visual. At the low end of the continuum of malleability, the Efficiency Frontier has two prespecified dimensions and a manager populates information according to these standardized dimensions. In the middle of the continuum, the value chain has a larger number of dimensions (nine dimensions); however, these dimensions are prespecified for a manager to populate. At the high end of the continuum, a manager can populate the scenario matrix with any dimensions and an unlimited number of attributes according to the selected dimensions.

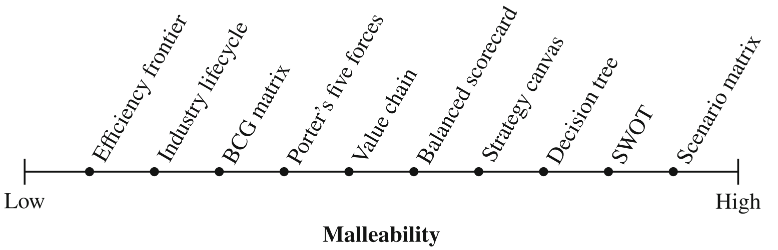

FIGURE 5 Continuum of malleability.

with low representational capability will lack sufficient understanding and thus become lost among all the possible options to create a decision tree, eventually developing one that has a vast search space, wherein good resolutions are rare. In sum, malleability has the following moderating effects on the problem space's size and satisfiability.

> **Proposition 4.** *All else equal, malleability will decrease the size of the problem space under high representational capability.*

> **Proposition 5.** *All else equal, malleability will decrease the satisfiability of a problem space under low representational capability.*

An interesting implication of this double-edged effect is that managers with low representational capability may well deliver better results when using relatively less malleable—or even nonmalleable—representations. That limitation would be akin to "training wheels" for the manager until he develops greater representational capability. This may explain the popularity of 2 × 2 frameworks in strategy.

5 | DISCUSSION

In this section, we first delineate the theoretical contributions of our research. We then discuss the implications for those creating and using external representations and, finally, propose ways to extend the nascent research on external representations in strategy.

5.1 | Theoretical contributions

Our study makes several contributions to the strategy literature. To begin, we explain why external representations—in the form of visuals—are so pervasive in strategy. Visuals are pervasive because they boost four cognitive functions that are crucial to SDM: working memory, long-term memory, pattern recognition, and knowledge transfer and transformation. In a nutshell, strategizing is cognitively demanding given the complex, unstructured, and high-stakes nature of strategy decisions (Eisenhardt & Bourgeois, 1988; Mintzberg et al., 1976, p. 246; Simon, 1962), and visuals allow strategists to tap into additional cognitive resources—those that lie in the roughly one-third of the human cerebral cortex dedicated to visual processing (Van Essen, 2004, p. 7).

Our cognitive explanation for why external representations are pervasive in strategy complements the sociological and communicational explanations provided by the literatures on strategy tools-in-use and on boundary objects, respectively (e.g., Jarzabkowski & Kaplan, 2015; Star & Griesemer, 1989). Along with these other literatures, our work indicates that external representations are deeply intertwined with SDM. We believe that, akin to the revolution in psychology where external representations transformed the understanding of cognition by shifting the focus from the mind to the "extended mind" (Clark, 2008; Paul, 2021), similar shift could occur within the realm of SDM. Rather than solely attempting to comprehend the "mind of the strategist" (Ohmae, 1991), the analysis could be directed toward understanding the "extended mind of the strategist."

In moving toward that goal, our paper extends the baseline understanding of SDM by incorporating external representations and showing how these affect decision-making quality. We show that external representations have a significant impact on the size and satisfiability of the problem space, influencing the likelihood of discovering successful solutions. We propose that managers differ in their ability to use good representations, which we call their representational capability. We also show that in order to make good decisions, managers should select external representations whose malleability is on par with their representational capability; otherwise, their search could go astray. Furthermore, we demonstrate how the usability of external representations can affect the results of the search process. In doing so, we expand the drivers of performance heterogeneity strategy research examines.

One implication of this way of thinking is that external representations have their greatest impact when used in the early stages of the SDM process, as this is when the space of possibilities is the most daunting. For example, during the stages of gathering intelligence and designing strategies (the first two stages of the SDM process, represented on the *x*-axis of Figure 1), managers face a challenge akin to a writer starting with a blank page: while an infinitude of stories can be written, only a few of them are potential bestsellers. In contrast, as the SDM process progresses to the later stages (such as choosing among alternatives and reviewing their effects); the space of possibilities significantly narrows: only a few choices are possible, akin to when the bulk of a novel is written and the writer can only make minor edits. In other words, coming up with "blue oceans" (Kim & Mauborgne, 2005) is more cognitively demanding than pursuing continuous improvement. Therefore, it is in these early-stage decisions when considering factors such as representational capabilities, malleability, and usability becomes crucial. This logic may also explain why the most emblematic external representations used in strategy tend to deal with the early stages of the SDM process (i.e., most of them appear on the left-hand side of Figure 1).

More generally, our work helps uncover the nuanced ways in which external and internal representations—visuals and internal cognition—relate to one another in the context of SDM. An interesting reciprocal relationship emerges from our theorizing, which we depict in terms of the two arrows in Figure 6. On the one hand, visuals shape internal cognition through enhanced cognitive functions that improve firms' ability to search. On the other hand, internal cognition can also shape visuals, as the process of selecting and populating a visual depends on the manager's representational capability. These two arrows roughly correspond with the arguments we elaborated when answering the "why" and "how" questions that motivate our research.

The fact that external representations operate in this manner calls for rethinking how our field conceptualizes the process of search. Search initially entered the strategy field as a way to increase the cognitive realism in models of competition and innovation (Levinthal, 1997). The

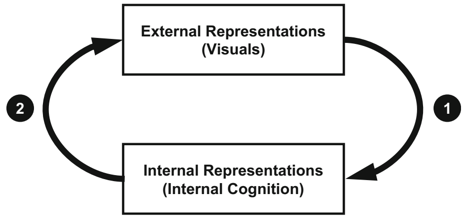

FIGURE 6 The reciprocal relationship between internal and external representations in strategy.

idea was that, unlike firms in economic models, real firms cannot see where the global optimum is and must instead incrementally improve from their current position. Researchers soon realized, however, that this view of search was still lacking in terms of cognitive realism, as a central concept in cognitive science—cognitive representations—had been left out. That is, individuals do not search on an exogenously given, fixed landscape, but the landscape is the result of a given way of "seeing" the world, which is the result of experiences, reflection, and cognitive constraints (Gavetti & Levinthal, 2000, p. 122).

This realization led to theoretical work to incorporate cognitive representations into models of search (Csaszar & Levinthal, 2016; Gavetti & Levinthal, 2000). Our work suggests that such an understanding of search is still incomplete because, as we have shown, external representations are used pervasively in strategy and they greatly affect the process of search. Consequently, future work on search processes within organizations should take external representations seriously (later in this section we provide some ideas on how to do this).

Our quest for increased realism is aligned with two calls for enhancing cognitive realism in strategy research. Eisenhardt and Zbaracki (1992, p. 33) advocate for research that aids in identifying the origins of managerial insights, while Gavetti et al. (2007, p. 532) urge the expansion of behavioral strategy through the incorporation of contemporary concepts from cognitive science. By introducing external representations into strategy, we help answer both of these calls.

5.2 | Implications for educators and creators of external representations

Strategy professors and consultants are instrumental in the creation, selection, use, and diffusion of external representations in strategy. Here we explore implications of our research for these professionals.

One implication is that those in the business of creating strategy ideas should acknowledge the value that external representations can add to their ideas. External representations should not be seen as mere decoration, but instead as powerful tools to boost managers' cognitive capacity and focus their attention on the most promising regions of the problem space. External representations not only help managers but the professors and consultants who design them, as external representations make it more likely that a strategy idea or framework will be understood, remembered, and used. A thought experiment may make this point clearer. Consider all the actionable strategy ideas presented in the academic literature, and then consider all the strategy ideas taught in the MBA program. One major difference between these two sets of ideas is that most of the latter involve an external, visual representation. This is probably not a coincidence, as it is reasonable to expect that strategy ideas accompanied by high-usability visuals will be more likely to be adopted. Recently, scholars have used similar arguments to recommend that research publications use more and better visuals (Ertug et al., 2018; Gelman et al., 2002; Greve, 2018).

Another implication for strategy professors is to be aware of the importance of external representations for student development. External representations, due to their ease of communication and internalization, offer perhaps the most expedient and reliable route for students to develop a broad repertoire of representations. Building this repertoire is important since previous empirical work has shown that the breadth of representations is one of the main predictors of decision quality in strategy (Csaszar & Laureiro-Martínez, 2018; Heshmati & Csaszar, 2024). Additionally, trying different external representations can have a similar effect as learning under conditions of related variation, resulting in improved learning and insights (Schilling, 2003).[16] In terms of the reciprocal relationship between external and internal representations depicted in Figure 6, the visuals that are taught in a strategy course shape students' internal cognition (arrow 1), which in turn will shape students' future use of visuals (arrow 2) and so on. In other words, the external representations taught in strategy courses are the seeds from which students' strategic thinking can germinate.

Finally, we believe that giving due importance to external representations in the classroom calls for making some changes to how strategy courses are taught. In particular, explaining to students the benefits of external representations, sequencing the presentation of different external representations in terms of increasing malleability, and providing guidance on how to pick among alternative representations.

5.3 | Implications for users: The powers and perils of external representations

External representations are powerful thinking tools that can enhance managers' cognitive capabilities and aid in developing high-quality strategies. However, as with all powerful tools, external representations have a potential for misuse. Here we expand on two ways in which external representations can become double-bladed swords, one at the individual, the other at the group level.

A first potential for misuse stems from one of the strengths of external representations: their capacity to enhance a manager's cognition by allowing a manager to capture a strategic problem in different ways. These news perspectives may produce a situation akin to the experience of the "flatlander" in Abbott's (1884) allegory who gains new insights when seeing the world in three dimensions for the first time (Adner & Levinthal, 2008, p. 44).

The flip side of this strength is that some of these alternative representations may have lower satisfiability; in other words, it becomes more difficult to find a satisficing solution because the "big picture" is obscured by superfluous details. One complicating factor is that individuals may be tempted to prefer complex representations, mistaking polish and additional data for validity (Griffin & Tversky, 1992). For example, Speier (2006, p. 1125) shows that individuals tend to have more confidence in solutions based on tables rather than graphics. The opposite problem is that the chosen external representation is an oversimplification; for example, that the crux of a problem is stakeholders that are not part of a five forces analysis. Mitigating these risks depends on managers' representational capability—that they use external

[16]We thank an anonymous reviewer for suggesting this idea.

representations in ways that make finding a solution easy. In practice, this calls for employing managers that have a large repertoire of external representations and are well-versed in their applicability.[17]

A second potential for misuse of external representations stems from their effectiveness in facilitating group communication. As described by the literature on boundary objects (Carlile, 2002; Star & Griesemer, 1989), external representations allow different parties to communicate and arrive at a shared understanding. The flip side of this strength is that external representations are an effective means to hijack the decision process for political purposes.[18] For instance, Barley (2015) shows that sometimes the anticipation of having to convince others ends up determining which external representation is used. This is further complicated because strategic decisions typically involve many stakeholders and, hence, are likely to be made by groups.

The implication is that strategic decisions, by their very nature, are made within group settings and are inherently political. March (1994) highlights the significant impact of coalitions and group dynamics on decision-making processes. Additionally, Kaplan (2008) demonstrates the entanglement of group politics and cognition, emphasizing that decision-making outcomes are influenced by the interplay between these factors. A noteworthy example of this phenomenon is presented in Kaplan's (2011) study, which examines how group politics shaped the struggle for control over the group's PowerPoint presentations, ultimately influencing the trajectory of strategic decisions. These findings imply that the selection and utilization of external representations cannot be divorced from the influence of group dynamics. As mentioned in the introduction, we believe that the "cognitive eye" we cast over external representations complements the communicational and sociological eyes cast, respectively, by the literatures on boundary objects and strategy tools-in-use. Fully integrating these three perspectives is one of the tasks awaiting future researchers, which we discuss next.

5.4 | External representations: A research agenda

Our paper amounts to an initial step toward understanding the central role that external representations, particularly visuals, play in the search for new strategies. It follows that there is much about this important phenomenon that remains to be studied. We next outline some of the questions that remain open and propose ways of addressing them.

First, additional research could examine how the use of external representations in SDM varies across individuals. One promising approach to exploring this question is the use of eye-tracking technology, which offers a previously unopened window into how individuals process visual information (Duchowski, 2002). Other ways of studying variation across individuals are by comparing how managers' experience (Lawrence, 2018) and roles (Tempelaar & Rosenkranz, 2019) affect how they use visuals.

Second, future studies could investigate how representational capability can be developed. One approach would involve conducting a classroom experiment in which different sections of a given course are taught using different types of external representations (or the lack thereof).

[17]For initial research on determining the optimal complexity of representations, see Csaszar and Ostler (2020).

[18]Ways in which focal actors achieve political purposes include engaging in political framing practices to make their frames resonate with others (Kaplan, 2008), manipulating the order in which alternatives are presented (Kleinmuntz & Schkade, 1993, pp. 226–227), and using statistics in deceptive ways (Bergstrom & West, 2020; Huff, 1954).

Comparing the improvement across the different sections in the ability to solve strategy problems would shed light on which external representations improve representational capability the most (see Csaszar & Laureiro-Martínez, 2018; Heshmati & Csaszar, 2024 for studies along these lines). One could also examine whether the added value due to a given visual is contingent on the type of individual (e.g., undergraduates or MBAs) and problem (e.g., corresponding to different stages of the SDM process illustrated in the x-axis of Figure 1; for initial research along these lines, see Eppler & Platts, 2009).

Third, scholars could examine in more detail how external representations affect search. Recall that the search literature has only studied internal representations. Incorporating external representations into the search literature could be done in several ways. One way is to study what happens when internal and external representations differ. For instance, one could study what determines the probability that an individual changes their mental representation when presented with a given external representation. Another way of studying how search depends on external representations is by extending the nascent experimental research on search (Baumann et al., 2019, p. 311) by measuring the extent to which different external representations, and possibly different group dynamics, lead to small or large jumps in the landscape (e.g., whether two-by-twos or open-ended frameworks are more or less likely to produce distant solutions and under what circumstances). In other words, how representational complexity (Csaszar & Ostler, 2020) affects exploration.

Finally, research could explore the use of computer-aided representations. To date, external representations in strategy have involved mainly the "low-tech" tools of pencil and paper. However, technological developments such as augmented reality and artificial intelligence offer interactive external representations that could enhance decision-making. Thus "computer-aided strategy," analogous to computer-aided design, could aid managers by identifying relevant information, synthesizing the opinions of multiple people and data sources, proposing problem-specific dimensions and frameworks, and collaborating interactively with strategists to find solutions. The recent advent of large language models like ChatGPT suggests that some of these ideas may become reality sooner than anticipated. Understanding these new ways of strategizing will require expanding the boundaries of existing research on external representations in strategy.

5.5 | Conclusion

This article has augmented the understanding of the SDM process by elaborating on the role that external representations play in it. We have pursued this objective by infusing SDM with new ideas borrowed from cognitive science. From a theoretical standpoint, we extend our knowledge about SDM by answering the two key questions of *why* external representations are so pervasive and *how* they affect decision-making. From a practical standpoint, we offer several managerial recommendations on how to use external representations in strategy more effectively. Overall, our research highlights that the design and use of external representations—much like navigation tools—hold consequences for decision-making quality; and, hence, that scholars and practitioners of strategy, akin to cartographers and navigators, can benefit from a better understanding of the constraints and possibilities afforded by these tools.

Although strategy is both pervaded and influenced by external representations, they have largely been ignored as a research subject. In that sense, external representations qualify as SDM's "elephant in the room." We are hopeful that the work reported here will bring more sustained attention to this central but understudied topic.

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DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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APPENDIX A: METHODOLOGY USED TO CREATE TABLE 1

Table 1 was compiled by analyzing the graphical content of the most popular MBA textbooks in various business fields, which correspond to typical "core" courses in MBA programs. For each field, we chose the three best-selling textbooks (as ranked by Amazon) that covered the core MBA course in that field. For each textbook, a research assistant—ruler in hand—measured the surface area of the book used by each different type of external representation as a percentage of the book's surface area that was devoted to graphics of all types. To maximize comparability, the analysis included only those parts of the book strictly related to course content; hence, we excluded such material as the preface, case descriptions, ornamental pages, the table of contents, indexes, references and footnotes, problems or exercises, and summaries. All measurements were made using the latest printed edition of each textbook. Also, we excluded the "management" core course that is part of many MBA programs as that course covers too great a variety of topics; depending on the school, it might cover strategy, negotiation, leadership, and/or human resources (indeed, many schools use their own material, rather than a textbook, for this course).