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Dialogue

More Enduring Questions in Cognitive IS Research

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Abstract

In the April 2012 issue of the Journal of the Association for Information Systems, Michael Davern, Teresa Shaft, and Dov Te'eni published an article titled "Cognition Matters: Enduring Questions in IS Research". Their paper reviewed much of the history of cognitive research in the IS discipline, especially that related to human-computer interaction and decision support systems. While we believe their article is excellent in many respects, we also believe that it omitted a great deal of the most basic cognitive research performed in the IS domain over the past 10-15 years, especially work in the area of systems analysis and design. Our purpose in this paper is to supplement the work of Davern et al. by discussing much of this recent work. We use two theoretical lenses to organize our review: basic cognition and behavioral decision-making research. Our review provides many illustrations of IS research in these areas, including memory and categorization (basic cognition) and heuristics and biases (behavioral decision making). The result, we believe, is a fuller picture of the breadth of cognition-based work in the IS discipline in general and systems analysis and design in particular. The paper provides further evidence of the importance of cognitive research in IS and suggests additional enduring questions for future investigations.

***Keywords**:Cognition, Systems Analysis & Design, Behavioral Decision Making, Memory, Categorization, Heuristics, Biases, Conceptual Modelling, Information Requirements Determination.*

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More Enduring Questions in Cognitive IS Research

1. Introduction

In “Cognition matters: Enduring questions in cognitive IS research”, which appeared in the April 2012 issue of the *Journal of the Association for Information Systems* (Vol. 13, No. 4), Michael Davern, Teresa Shaft, and Dov Te’eni examine the role of cognitive research in information systems research and make the case for a promising future for this stream of work. In this work, we respond to that paper.

We believe that Davern, Shaft, and Te’eni’s paper is excellent in many respects. It covers cognitive work performed in the IS field in decision support systems (DSS) and human-computer interaction (HCI) particularly well. However, the authors omit some very important research in other areas of IS and neglect some of the most basic cognitive research that has occurred in the IS field over the past few years. This dialogue paper not only identifies and discusses additional cognitive research in the information systems field, but also points to further enduring questions in cognitive IS research that supplement Davern et al. (2012).

We frame our discussion using systems analysis and design (SA&D) as our main organizing principle. Although Davern et al. (2012) discuss SA&D (Section 3.2 of their paper), their treatment is largely historical, does not figure prominently in their paper, and ignores much recent cognitive research in this area. Systems analysis and design is a core activity in the IS field (Bajaj, Batra, Hevner, Parsons, & Siau, 2005), which we believe deserves more coverage than Davern et al. provide. In this paper, we identify and discuss additional recent cognitive research in the area. We address the research using two theoretical lenses that have been utilized by researchers: basic cognition (e.g., memory, categorization) and behavioral decision making (e.g., heuristics and biases). We believe these additions illustrate more fully the breadth of cognitive research in the IS domain, as well as its impact on the field. As this is a dialogue paper, our discussions feature only illustrative research examples and we do not attempt a comprehensive review of additional studies of cognition in the discipline.

Systems analysis and design is the process through which information systems are planned, analyzed, designed, and implemented, and it is a central activity in the IS field (Kendall & Kendall, 2010; Valacich, George, & Hoffer, 2011). Research has been performed on all SA&D activities, both in the systems development lifecycle (SDLC) (i.e., “waterfall”) and “agile” paradigms. Although we will speak in the language of the SDLC, the discussion generally applies equally to agile approaches to systems development.

Following the “representational model” proposed by Wand and Weber (1990), Davern et al. (2012) frame their analysis in terms of “information systems as representations (p. 275). Indeed, the key early representations in systems analysis and design are cognitive, both in the minds of users or clients and (later) of analysts. Communication between users and analysts frequently relies on sharing cognitive representations of a domain, which are often supported by external representations such as conceptual models. However, Davern et al. do not explore in any depth the relationship between cognition and representation in systems analysis and design.

2. Model of Cognition

In Figure 1 on page 275 of their paper, Davern et al. (2012) provide a model, or framework, for their research that is based on the model first described by Card, Moran, and Newell (1983). Their framework is very general and quite reasonable. However, the model’s descriptions of cognitive processing consist of two clouds labeled “developer mental representations” and “user mental representations of IS and real-world task”. Although Davern et al. use textual descriptions to help explain these clouds, we utilize a different approach to open what are essentially black boxes. We present our model in Figure 1, which is a partial expansion of what is contained in the clouds presented by Davern et al.

As can be seen, ours is a simple conceptual model of cognition based on psychological models that distinguish between working memory and long-term memory (Atkinson & Shiffrin, 1968; Cowan, 1993; see also Cowan, 2005; Healy & McNamara, 1996; Hitch, 2012; Rutherford, Markopoulos, Bruno, & Brady-Van den Bas, 2012). Consistent with Davern et al. (2012, p. 276), it omits the perception construct because perception has not played a significant role in cognitive IS research. Instead, our model depicts working memory and long-term memory, their primary activities (for working memory) and contents (for long-term memory), and the processes of storage into and retrieval from long-term memory. In addition, we show categorization and biases outside the two memory systems and associated processes to emphasize them in our discussion (although they are, of course, within the cognitive system)[1]. Constructs appearing in italics are the focus of our discussion; they have been addressed in cognitive IS research but are not discussed (or not emphasized) by Davern et al. The level of resolution of cognitive constructs in our model allows us to describe issues and ask questions that Davern et al. did not.

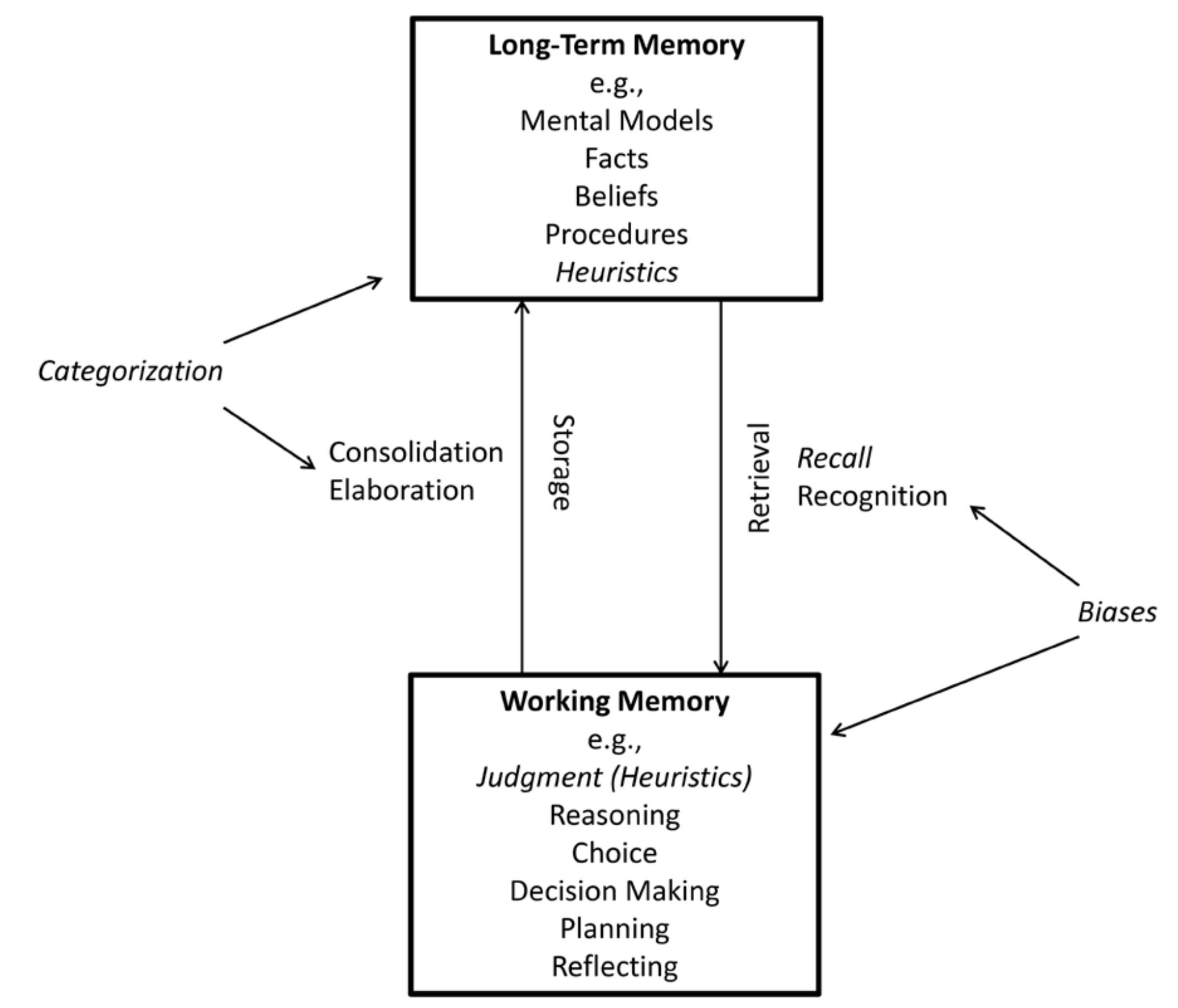

Figure 1. Analysts' and Users' Mental Representations

[1] We note that there are many different ways of modeling memory conceptually; some researchers use only one memory construct (e.g., Crowder & Neath, 1991; see Healy & McNamara, 1996, for a full discussion) and many other complex models have been suggested. Most researchers find distinguishing between working memory and long-term memory useful, and that is the approach we have adopted. Note also that, because ours is a conceptual model, it illustrates what occurs, but not where or precisely how it occurs in the brain.

3. Research on Basic Cognition in Systems Analysis and Design

Several important streams of research in basic principles of human cognition have appeared recently in systems analysis. In discussing these streams, we are consistent with Davern et al.'s statements in Section 2.3 (p. 277) of their paper: "However, our historical analysis reflects the evolution of cognitive research in IS, not cognition research more broadly…not surprisingly, in our historical investigations we found that the evolution of cognitive research in IS has been primarily driven by the challenges and questions arising in IS, rather than by advances in cognitive theory and method. As such, IS is the source of these questions, whereas the cognitive literature is a source of useful theory and methods for addressing these questions". The research streams we discuss in this section are driven by problems in systems analysis and design, not by problems in cognitive psychology.

One issue concerns human memory. Memory plays a critical role in all behavior. Significant work in recall from long-term memory has been performed in the information requirements determination (IRD) activity of systems analysis, in which relevant knowledge is elicited from stakeholders. For example, Moody, Blanton, and Cheney (1998) investigated cognitive interviews as a method for eliciting requirements by utilizing principles of memory retrieval from cognitive psychology. They found that cognitive interviews elicited recall of more relevant and more complete information from users than standard requirements interviews. Two recent papers by Appan and Browne have also addressed long-term memory issues in IRD. In a 2010 *JAIS* paper, Appan and Browne (2010) investigated "retrieval-induced forgetting" (RIF) in response to problems in information requirements determination. Briefly, RIF refers to the fact that information originally recalled by someone (e.g., a system user) in response to a stimulus suppresses related but currently unrecalled information in that person's long-term memory. If the person is asked to recall information on the same topic at a later time, they are likely to recall the same information as they originally recalled because other relevant information has been suppressed in their memory (see MacLeod, 2002, for a general discussion). Appan and Browne empirically showed the potentially deleterious effects of RIF on requirements determination, particularly the likelihood that much relevant information will not be recalled by users. In a second, unrelated paper, Appan and Browne (2012) investigated a psychological phenomenon known as the "misinformation effect", which also concerns recall from long-term memory (see Lindsay, 1990, for a general discussion). The misinformation effect occurs when a person receives misinformation (false or erroneous information) concerning an event after witnessing the event. When asked to report what they saw, the person reports the misinformation rather than what they originally witnessed. Appan and Browne (2012) empirically demonstrated that the misinformation effect can occur with users' knowledge and beliefs in a requirements determination setting, and they showed the effect's dangers for systems development and the potential mitigating actions that might be taken.

Another basic cognitive phenomenon that has received significant attention in SA&D is categorization. A stream of IS research developed in this vein focuses on theories of concepts, classification, and categorization (Lakoff, 1987; Rehder & Burnett, 2005; Rosch, 1978; Smith & Medin, 1981) and their potential implications for conceptual modeling and database design. Parsons (1996) first proposed that cognitive theories of concepts could be used to develop information modeling constructs that better reflect how humans organize knowledge about a subject domain. That and subsequent research (Parsons & Wand, 1997) proposed formal information modeling constructs based on the cognitive principles of economy and inference that underlie concept formation (Rosch, 1978). Use of these principles led to guidelines for selecting classes and for developing "good" collections of classes to represent a domain based on the criterion of cognitive inference (Parsons & Wand, 1997, 2008b). In addition, recognizing that classification is purely a cognitive phenomenon, Parsons and Wand drew a fundamental distinction between instances and classes, which allowed multiple classification structures to co-exist over a domain of instances (in contrast to attempting to identify a single correct classification structure). This work led to the instance-based data model, a logical data model that manifests the instance-class distinction and stores information independent of any classification (Parsons & Wand, 2000). This research in IS has also been applied successfully to understanding more general questions of classification in science, such as the criteria for classifying celestial bodies as planets and the concept of species in biology (Parsons & Wand, 2008a).

Cognitive theory has also been used in conceptual modeling research to help explain why certain modeling practices are more effective than others. For example, Gemino and Wand (2003) drew on Mayer's work on models of learning (Mayer, 1989) to adapt techniques used originally in cognitive research to experimental studies of conceptual modeling. Additionally, Gemino and Wand (2005) adapted the cognitive theory of multimedia learning (Mayer, 2001) to explain why using mandatory properties in conceptual models promotes understanding of a domain better than using optional properties. Parsons (2003) used cognitive principles of classification to study the effects of global versus local schemas on users' understanding of conceptual models. Such studies have enhanced our understanding of the effectiveness of conceptual modeling theory and practice.

Another cognitive issue in systems analysis and design is the decision in information requirements determination, and in information search more generally, of when to stop gathering information. Systems analysts can, in theory, interview users for indefinite periods of time, but, in practice, they (of course) do not do so. Certain heuristics (i.e., cognitive rules of thumb based on reasoning or judgment) for stopping have been theorized and empirically tested in IRD. Browne and Pitts (2004), utilizing cognitive stopping rules hypothesized by Nickles, Curley, and Benson (1996), examined the stopping rules used in a requirements determination task with 54 practicing systems analysts. Browne, Pitts, and Wetherbe (2007) later extended this work on cognitive stopping rules to information search more generally. This research has resulted in both descriptive and prescriptive implications for systems analysis and design. Analysts do not gather all appropriate information for software applications, and the costs of over-acquisition (wasted time and money) and under-acquisition (insufficient requirements) and the trade-off between them should be taken into account when considering analysts' stopping rules. The research has resulted in a better theoretical understanding of cognitive processes in information search generally and in IRD in particular.

Mental models have also played a role in IS research on SA&D. Mental models are organized cognitive structures containing declarative, procedural, and episodic knowledge about a concept or situation (Rouse & Morris, 1986). Although Davern et al. (2012) provide a good discussion of expertise (Section 3.3), their discussion of mental models omits important research performed in the IS field, especially during requirements elicitation. For example, in their investigation of a process model of requirements elicitation, Chakraborty, Sarker, and Sarker (2010) discuss the development of mental models during elicitation. They find evidence of attempts by analysts and users to build shared mental models of the application environment. Davidson (2002) and Urquhart (1997) have also investigated the development of mental models during requirements elicitation.

Space considerations prevent us from discussing other basic cognitive research in SA&D in detail, but we will mention several other studies that are representative. Although Davern et al. (2012) discuss some of these issues in various places in their paper, they omit such research in the area of systems analysis and design. Montazemi and Conrath (1986) performed early work in cognitive mapping in IRD. Jun, Butler, and King (2007) investigated team cognition in software development. Griffith and Northcraft (1996) looked at cognition in new technology implementation and investigated the impact of frames, values, shared information between analysts and users, and amount of information on implementation. These are just several of many studies that have investigated additional basic cognitive issues in systems analysis and design.

Recent work on basic cognition in systems analysis and design suggest many enduring research questions. Examples include:

1. How do users' and analysts' memory structures impact requirements determination and systems development? For example, is misinformation supplied by users (as opposed to analysts) in the systems development process? If so, what are the dangers for systems development? How can the problems be mitigated?

2. How can the differing mental models of problem spaces of analysts and users be reconciled to improve requirements elicitation?

3. What is the impact of cognitive stopping rules throughout systems development (and other areas of IS, such as web search)? For example, what stopping rules do systems analysts use when constructing conceptual models?

4. How can conceptual modeling grammars be designed to facilitate better understanding of and communication about domain semantics? What are the implications of better modeling grammars on the quality of information systems?

4. Research on Behavioral Decision Making in Systems Analysis and Design

Behavioral decision making is a broad field of inquiry that encompasses many cognitive and behavioral constructs. It is probably best known for the work by many scholars on cognitive heuristics and resulting biases. Some IS scholars have used behavioral decision making constructs to investigate issues in systems analysis and design. The literature from behavioral decision making is largely ignored in Davern et al. (2012).

Heuristics are cognitive short cuts, or rules of thumb, that allow people to act and decide with relative speed and accuracy. People develop heuristics as they gain experience with a task, and heuristics generally improve (that is, become faster and more accurate) as a person's expertise increases. Most heuristics are idiosyncratic to a particular person, but some heuristics have been identified that are universal (Tversky & Kahneman, 1974): these include availability, representativeness, and anchoring. A full discussion of heuristics is beyond the scope of this paper, but the interested reader is referred to Bazerman and Moore (2009), Gigerenzer, Todd, & the ABC Research Group (1999), Kahneman (2011), Simon (1996), and Tversky and Kahneman (1974).

Because heuristics are short cuts, they do not result in optimal outcomes (except by chance) in any but the simplest problems. The errors that result from the application of heuristics are both random and systematic. Systematic errors (that is, systematic deviations from a normatively correct answer or standard) are usually referred to as biases. Discussions of biases in requirements determination specifically and systems development more generally (as well as other IS contexts) are available in Arnott (2006), Browne and Ramesh (2002), Stacy and McMillan (1995), and West (2008). Although all biases are cognitive, for research purposes, investigators have usefully divided biases into "cognitive" and "motivational" biases (Bazerman & Moore, 2009). Cognitive biases are caused by the ways in which people process information (e.g., processes involving perception, attention, working memory, and long-term memory). Motivational biases are caused by internal preferences or desires and by external forces and incentives in the decision making environment. Both cognitive and motivational biases have been investigated in systems development contexts. In the following paragraphs, we discuss several research streams concerning biases in systems analysis and design.

One type of motivational bias is non-rational escalation of commitment, and the work by Mark Keil and colleagues (e.g., Keil, 1995; Keil, Mann, & Rai, 2000; Mähring & Keil, 2008) is perhaps the best-developed stream of research using a construct from behavioral decision making in the IS domain. Keil's focus has been on the management of IS development projects and therefore is directly concerned with issues in SA&D. Non-rational escalation of commitment is a cognitive phenomenon that refers to continuing with a project or other commitment after an economically rational person would have stopped (Bazerman & Moore, 2009; Staw, 1976). Keil has used a broad range of theories to help explain non-rational escalation of commitment in systems development projects, including cognitive theories (self-justification theory, approach-avoidance theory), behavioral decision making theory (prospect theory), and economic theory (agency theory) (Keil et al., 2000). Keil's body of work provides a relatively comprehensive understanding of how and why software development projects escalate non-rationally, and potential remedies for runaway projects. In addition to Keil's research on the topic, other researchers have also addressed escalation of commitment in systems development. For example, Heng, Tan, and Wei (2003), using feedback and accountability as predictive variables, looked at escalation of projects from a motivational perspective.

An important cognitive bias also results from anchoring on an initial value and failing to adjust away from that initial value adequately (Epley & Gilovich, 2001). Jayanth, Jacob, and Radhakrishnan (2011) studied the anchoring bias in requirements elicitation in the context of a vendor-client relationship; they found that the bias exacerbates the influence of non-neutral prototypes in leading the client toward specific requirements. Parsons and Saunders (2005) examined the role of anchoring and adjustment in the reuse of code and of conceptual models. They found that developers anchored on existing code or models when reusing them in a new situation. In particular, they demonstrated a strong tendency to retain extraneous functionality – that which existed in the artifact to be reused but not specified in the requirements for the new application. Similarly, Allen and Parsons (2010) found evidence of anchoring in the reuse of a different type of IS artifact – SQL queries. That study also examined the effects of domain familiarity and type of anchor (surface vs. deep) on the extent of successful adjustment. Together, these latter two studies used a foundation from cognitive research to provide cautionary evidence that artifact reuse in IS, a practice widely assumed to be desirable, needs to be approached with caution. Strategies might be needed to mitigate adjustment biases when reusing IS artifacts during SA&D.

Another cognitive bias that has been observed in systems development is the status quo bias. The status quo bias refers to people's (in this case, users') desire to maintain current conditions, operating procedures, or status (Samuelson & Zeckhauser, 1988). In systems development, Kim and Kankanhalli (2009) have demonstrated that the status quo bias is an explanation for users' resistance to change.

The psychological problem of framing effects has also been studied in IS contexts. When the same problem is presented in two different formats, and people make different judgments or choices due to this different "framing" of the problem, framing effects are said to occur (Kahneman & Tversky, 1984). In Heng, Tan, and Wei's (2003) study investigating software development projects, the authors tested for optimistic and pessimistic framing of feedback on people's willingness to continue with a software project and found different effects for the different frames.

Numerous other cognitive and motivational biases have been the subject of research in systems development and other areas of IS. Cognitive biases and methods for overcoming them in IRD were investigated by Browne and Ramesh (2002) and Pitts and Browne (2007). Other biases investigated include the base-rate fallacy (e.g., Lim & Benbasat, 1997; Roy & Lerch, 1996), the illusion of control (e.g., Xiao & Benbasat, 2007), the overconfidence bias (e.g., Tan, Tan, & Teo 2012), and regression toward the mean (e.g., Jørgenson, Indahl, & Sjøberg, 2003). As with the basic cognitive issues, the research on biases discussed in this section is merely illustrative of the types of research that have been performed in SA&D and the IS discipline more generally.

Despite the examples cited in this section, we believe heuristics and cognitive and motivational biases in systems development and IS more generally is an under-researched topic in the domain. Enduring research questions arising from this domain include:

1. What other effects does the anchoring bias have on requirements elicitation and conceptual modeling? What effect does it have on the remainder of the SA&D process? How does the framing of a problem affect requirements elicited? What is the impact of framing effects on conceptual modeling and system design?

2. What additional cognitive and motivational biases affect analysts and developers in eliciting requirements, developing conceptual models, and designing and implementing systems? What mitigating strategies can systems analysts use to reduce the impact of cognitive and motivational biases?

3. How do the heuristics that analysts employ impact the systems development process? What heuristics do they use? What are their costs and benefits? What is the impact on eventual systems quality, adoption, and use?

5. Discussion

Cognitive research has played an important role in the development and understanding of information systems. Davern et al. (2012) did an admirable job in reviewing much of this research. All research is selective, however, and we believe Davern et al. were overly selective given that their goal was to provide a historical perspective and insight into enduring topics and questions of interest. The research reviewed in this dialogue paper illuminates a broader landscape of cognitive research that has occurred in the IS area in general and systems analysis and design in particular. The management information systems domain has been acknowledged to have important roots in behavioral science, and behavioral science has long been dominated by attempts to understand human information processing and motivations. Cognitive research has been approached from many different perspectives in behavioral science. In this paper, we address the topic from two perspectives: basic cognitive research and behavioral decision making research. We chose these perspectives because much IS research has utilized them and we believe they were not adequately addressed in Davern et al. Numerous other perspectives also exist, such as mental imagery theories and dual-processing theories of cognition. Because this is a dialogue paper – that is, intended to inspire discussion but not provide a comprehensive review – this paper is also selective in its coverage of topics.

The research reviewed in this paper points to several concerns with Davern et al. (2012). While we agree with most of their assertions and conclusions, there are some places where we differ. For example, on page 283 of their paper, the authors provide a one-paragraph review of requirements determination research and state: "Despite its importance to software development, requirements development has not been subject to extensive research". Later on the same page, the authors conclude their discussion by stating "Despite the importance of requirements determination and ample historical motivation for its investigation, these studies appear somewhat piecemeal, achieving little coherence". We beg to differ. Beginning with Davis' (1982) seminal work, requirements determination is one of the better-developed and more thoroughly researched topics in the IS domain. Hundreds of studies have brought theoretical and practical insights on the topic, such as methods and techniques, problems and remedies, and individual versus group elicitation issues. As noted in our review, much recent cognitive research has addressed requirements determination issues in human memory, cognitive stopping rules, mental models, and judgmental biases. Davern et al.'s paper does not devote adequate attention to the topic, omits many key citations, and does not provide a thorough analysis.

Likewise, Davern et al.'s (2012) paper largely ignores a significant body of research on cognitive research in conceptual modeling. This is somewhat surprising because they explicitly framed their paper in terms of Wand and Weber's representation model, yet paid little attention to the contribution of cognitive research in understanding the implications of how domain knowledge is represented during systems analysis and design. As we show in this discussion, cognitive research has been performed on categorization, which has led to improvements in both the theory and practice of conceptual modeling and on the anchoring bias and other issues in conceptual modeling.

6. Conclusion

As this paper demonstrates, much cognitive research has been performed in the systems analysis and design domain. The breadth of cognitive research in IS is much greater than the issues discussed in Davern et al. (2012). This dialogue paper describes other important areas of research in IS in which cognitive approaches are being utilized. These areas provide additional enduring questions for cognitive research in information systems.

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