Commentary

Explanations in Design Thinking: New Directions for an Obfuscated Field

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Abstract Design plays an integral role in the functions of modern society. Yet the abstract process by which designers carry out their work is not obvious. The study of design thinking has grown in recent years into a major area of academic research, yet it presently lacks a clear theoretical basis; and as a discipline, its methodologies are disparate. Here, we outline and clarify the framework of the scholarly study of design thinking, introducing the major ideas and concepts upon which the field is based. We then discuss in detail the various methodological issues of the field, and argue that, in its current state, the field of design thinking cannot sustain itself as an independent area of academic research. We suggest that design thinking may best be studied from a sociological or science, technology, and society (STS) studies perspective.

Keywords Design Thinking; ambiguity; cognitive science; justification; explanation

Dimensions of Design

Virtually all aspects of our daily lives are, in some form or another, designed. Everything from the alarm clock that wakes us up in the morning, to the public transit network that takes us to work, to the home we return to in the evening is a product of design. But how does a designer determine how to design such products? This is the role of design thinking. In order to grasp what design thinking is, it is important to understand the various objects, actors, and processes that come into play in the process of design. First of all, the actual activity of design is notably *not* an academic activity; the actors who engage in design practices are not academics, but rather, they are industry professionals. Designers are the people who work within particular sectors of the working world to create solutions to specific problems that are often unique to their sectors. For instance, in the corporate world designers may help to develop new workflow procedures, managerial techniques, and so forth to help increase the efficiency and efficacy of a working group. Fields such as architecture and urban design are largely populated by designers, who apply themselves to finding novel solutions to problems related to how the members of the public experience the spaces they live in, and many areas of the arts, such as theatre and fashion, are intimately connected to design.

Importantly, as actors in the world, designers report to another category of actors, namely the consumer. Often, the consumer fills the role of the problem *creator*, whereas the designer acts as the problem *solver*. Consumers include the people who hire the designers for particular projects, as well as those who are affected by the realization of the designer's work. For example, if a manager of a senior corporation hires a designer to improve the workflow process of their company, then both the manager and the employees are consumers of the designer's products. Thus, the category of consumers includes not only those that engage in some kind of an exchange with designers, but it also includes those that are impacted, either directly or indirectly, by the work of designers. In short, the category of consumers can include those that create problems requiring design solutions, those that hire and interact directly with the designers, and those that are affected by designers' work. No doubt, an individual may belong to a number of these sub-categories.

In solving a problem, a designer produces a product, be it a building design, a material consumer product, a costume for a theatrical production, and so forth, which is then consumed for its intended purpose. One labels the process by which a designer arrives at the solution to some particular problem "design thinking" or "designerly thinking" (some authors have provided more nuanced accounts of these terms and their differences; here we take them to be identical). The final layer of this system, then, is the scholar or academic who seeks to understand the processes underlying design thinking. These scholars treat design thinkers as epistemic agents and attempt to study the formation and manipulation of knowledge

by them, together with their implicit problem-solving processes, as well as the mutual interactions between designers, design products, and consumers. These academics work at universities, they publish in journals, and they attend conferences on the subject matter. Importantly, the primary object of their study is the *(implicit) thought processes of the designer*. This is summarized in the following Table 1:

Table 1. Actors, processes, and objects of design thinking.

Actor	Process	Object
Consumers	Finding or creating problems that require innovative solutions; entering in exchange relationship with designers; consuming the products of designers.	*Create* problems for, enter in *exchange* relationships with, and *consume* the products of designers.
Designers/ Design Thinkers	Designerly or design thinking; solving problems assigned to them.	*Create* tangible and intangible products that solve problems.
Design Scholars	Understanding the underlying principles, methods, and thought processes.	*Study* the processes of designerly thinking.

Following Nigel Cross,[1] it is valuable to compare and contrast design as a mode of inquiry with two other major modes of inquiry: the sciences and the arts. Specifically, Cross argues that all three are effectively determined and mutually differentiated from one another by three factors: the phenomena of their study, the methods of their inquiry, and the values of their practitioners. Roughly speaking, the sciences study physical phenomena, whereas the arts study the phenomena of human experience. Scientists conduct research using methods such as controlled experimentation, data analysis, and mathematical modeling, while the methods used by artists include rhetoric, analogy, and prose. Finally, the cultural values in the sciences tend to be neutrality, objectivity, and rationality; the values embodied by the social organization of scientific actors can be expanded to include communism, universalism, disinterestedness, and organized skepticism.[2] The values of artists tend to be subjectivity, creativity, and imagination. For Cross, the corresponding features for designers are as follows: the phenomena under study are those of the artificial, or man-made (created) world; the methods (or modes of inquiry) include modeling, pattern-formation, and synthesis; the cultural values include practicality, empathy, and ingenuity.[3]

To begin inquiring into the principles underlying design – the purported aim of design scholars – it is necessary to provide a more exact notion of what design is. One definition of design is "the conception and realization of new things."[4] Let us unpack this. "Conception" has to do with a kind of mental activity, especially one that relates to understanding a problem and conceiving novel solutions to it. "Realization" is usually the *physical* instantiation of a solution (creating a new product, for example) but realization may also take a *mental* or conceptual form (as in reflexive amendments). Whereas conception *simpliciter* may be thought of as initial problem-formulation and conceiving of novel solutions, conception within realization is more appropriately understood as a mental representation that gets amended as a result of alternative physical or conceptual realizations. Consequently, conception and realization are often causally bidirectional – conceptually or physically realized products can influence designers' conceptions of how well they work, and so new or amended products may be conceived and realized. Specifically, the realization that causally impacts a conception could be a physical realization, in which case one literally perceives that a design solution is ill-suited to a specific problem. Or it could be a mental realization, in which case one's experimental *thinking* alters the conception. Finally, "new things" refers to the physical instantiation of a solution that was initially conceived of in the mind as a potential remedy for a specific problem. To consolidate this, the process of design amounts to the *conceiving of a solution to a specific problem and then intentionally intervening in the physical world to instantiate that solution*. For simplicity's sake, we have excluded from the definition the reciprocal relationships that obtain between conception and realization. In short, the act of design is the physical instantiation of a mental representation, which is conceived of as a solution to a particular problem.

There are distinct forms of knowledge that manifest themselves in the field of design. This is not an outlandish claim, as it is already well-established within, for instance, the Science, Technology, and Society (STS)[5] community that distinct cultures often possess different forms of knowledge, and indeed have epistemologies that drastically differ from those of others.[6] Design may thus be understood as a culture that is vastly distinct from the sciences and the arts, and by implication, one that possesses its own forms of knowledge. The knowledge of designers primarily differs from that of, say, scientists due to its predominantly *tacit* or *practical* technological form.[7] This type of knowledge is mostly gained via practical problem-solving, let alone via theoretical understanding alone.

Let us combine the inchoate definition of design as

the "conception and realization of new things" with the idea that design thinking is primarily centered on problem solving. This raises the question: "How does a process of this type take place?" Here, we provide an outline of what one such process may look like, or more radically, some of the features that may be common across various design processes.

The process often begins with the designer directly perceiving a set of objects, thus creating a mental representation of them that is augmented by understanding the relations between them. These relations are not directly perceived, since they do not exist in the physical world. Rather, the designer understands them only implicitly; for more complex representations, however, conscious effort may be required to adequately represent the set of objects perceived and, especially, to comprehend the relations that obtain between them. Within the cognitive realm, the designer may find solutions to the problem by engaging in thought experiments, spatially rotating the objects, rearranging the relations, etc. These activities are motivated with the goal of finding a practical solution to the problem, not understanding the nature of the problem itself, though some understanding is a requisite for any adequate solution. In order to aid her thinking, the designer may create various physical models that make her mental representations more concrete. A model may then be implemented in the form of a physical object, which constitutes a solution to the initial problem. It is the physical implementation of the solution that is referred to as the "design product," and since most of design thinking is oriented towards solving concrete problems – in architectural, urban planning, and managerial contexts, for example – these final, physical products are part and parcel of the work of designers. Needless to say, any stage in the process can impact any of the preceding stages and, in fact, most effective design products are rarely, if ever, implementations of the solution first conceived. Rather, the final implementations that prove effective undergo reciprocal changes in an iterative fashion, including those induced by other designers, interlocutors, and perceptual and cognitive phenomena. In short, the design process begins with perceiving a problem and ends with physically implementing a solution to it – though this does *not* imply that the physical implementation does not stimulate ideas and solutions for *other* problems.

Having provided this outline, some general remarks about the differences between how scientists and designers approach their problems are in order. It was remarked above that designers generally are not concerned with understanding the nature of a problem in its entirety, and instead predominantly care only about finding solutions. Scientists, on the other hand, when faced with a problem, generally adopt a protocol whereby they learn as much as they can, often at great intellectual expense, about the nature of the problem itself and the underlying rules governing what may constitute a viable solution. Scientists often take the process of problem-solving to be largely exploratory; these offer opportunities to better understand the underlying rules governing the behavior of explananda. By contrast, the general protocol of designers is to try a number of different solutions until one of them works. Indeed, in an experimental study where designers and scientists were asked to organize blocks in such a way that they would satisfy a set of rules, some of which were never explicitly stated, the scientists generally took the strategy of exhaustively trying different attempts with the goal of learning all of the rules, and then trying to satisfy them. The designers, by comparison, generally did not take this strategy, instead opting more frequently for a procedure of guessing using creative attempts in search of a solution.[8] The designer's approach indicates that understanding the nature of the problem serves a role that is subservient to the task of finding a workable solution. A problem is to be understood insofar as it helps in finding a solution. Here, the underlying assumption is that the value of a designer's work is assessed in terms of its pragmatic utility, whereas the value of a scientists' work is assessed largely by the consistency of their theories with experimental results (in light of the precision of the relevant instruments).

Echoing the idea that varying cultures often embody different epistemologies, we see an analogy between, on the one hand, scientists and coherence theory of truth and, on the other hand, designers and pragmatist theory of truth. If one adopts a coherence theory of truth, then one views the degree of truth of a set of propositions as being proportional to their mutual coherence and consistency.[9] If, however, one adopts a pragmatic theory of truth, then one measures the truth of a collection of propositions by the degree to which it enables one to succeed at completing tasks in the world.[10] Analogously, scientists may be viewed as *coherentists* about the products they produce – theories, experimental observations, technical instruments – in the sense that they are predominantly occupied with constructing theories and performing highly precise measurements that are mutually consistent. However, by the same token, designers may be understood as *pragmatists* about their products because they are largely, if not exclusively, driven by the need to accomplish some sort of task. Importantly, reference to the

coherence of their design *processes* and tools is seldom present, and often, it is entirely absent. Indeed, contradictions in design processes are notably difficult to provide a theoretical account for.[11]

Nevertheless, science and design are not mutually exclusive categories. Rather, they inhabit diametrically opposed ends of the same continuum. One example in which scientific approaches and design practices coexist is in the research and development (R&D) departments of various corporations. Here, the need for expedience often overpowers scientific rigor in part because the motivation for applying scientific tools is production of products, which is inherently pragmatic. The corporate structure often undermines scientific rigor by failing to encourage article publications, peer review, etc. It appears, then, that people working in the R&D sector of private industries combine parts of coherentist and pragmatist theories of truth, and they give each a different degree of importance depending on both their goals and the stage of the research process they may be in.

The Problematic Practices of Design Scholars

We have thus far provided in outline a framework within which to understand design and design thinking. Recall that design scholars are academics who aim to understand the principles underlying design processes and designerly thinking. The purpose of this section is to evaluate the work of design scholars (not designers, who are merely the object of study of the design scholars). Our discussion is largely delimited to the methods of design scholars and to what constitutes justification in the field, though our criticisms are connected to the theoretical content of the field. We conclude that the work of design scholars has foundational shortcomings.

Ambiguity

Ambiguity is to be understood as a measure of how ill-defined the terms and concepts, and how underdetermined the theories in a field are. Put differently, ambiguity corresponds to how prone a reader of a field's literature is to misunderstanding or misinterpreting the claims made, even after being sufficiently exposed to the fundamentals. Undoubtedly, almost all academic disciplines are ambiguous to varying degrees, since it is virtually impossible to present a complex idea in such a way that no room is left for misinterpretation or misunderstanding. Pure mathematics, which is completely axiomatic-deductive in nature and where every term is explicitly and precisely defined, is *almost* an exception, and would correspond to the closest thing academia has to a perfectly unambiguous discipline. Moreover, the degree to which ambiguity characterizes each discipline varies widely. For instance, physics is generally very precise in its use of technical terminology, which is often couched in mathematical formalisms that bear some explicit correspondence to physical entities in the world. Other fields, notably humanities or social scientific fields like STS, are more ambiguous in their terminology. For instance, it is very hard to find a definition that is unique and not merely intuitive for a term like "social construction." Generally speaking, fields that operationalize their variables in quantitative terms tend to be less ambiguous than those that rely on qualitative descriptions. The quantitative and qualitative characterizations often neatly map onto the sciences and humanities, respectively, though there are exceptions and other differences between the two modes of inquiry.

Our comments on ambiguity are not be taken to mean that any field that is ambiguous is somehow degraded or less valuable. After all, poetry and literature, both of which permit deep academic investigation, are both extremely ambiguous quite frequently, and indeed this is a virtue for them, as they would lose their value if they read like scientific articles. However, disciplines that (implicitly) purport to study in a robust manner the general principles underlying the workings of a given phenomenon ought to be more precise. Ambiguity is never to be valued for its own sake, and arguably, not for its consequences either because its proliferation leads to loss of clarity. With these preliminary remarks in mind, we now illustrate not only that an unacceptably high degree of ambiguity is a pathological feature of academic work in design, but also that the methods of design thinking scholars effectively perpetuate this ambiguity. Importantly, our analysis is primarily based on a number of papers recently published in this journal.[12]

A ubiquitous problem in the field is the ambiguity surrounding the methods and practices of design scholars. The first problem is that it is unclear what "design thinking" actually refers to.[13] Is it supposed to be a type of scientific inquiry? Is it a social practice? Is it a mode of critical thinking or of artistic pursuit? Furthermore, the literature on design does not specify whether design thinking is an object of study, or whether it is a set of methodologies and practices of the scholars themselves. If it is the former, then inquiry into its nature is the task of design scholars. If it is the latter, then these constitute techniques for studying the nature of some other phenomenon (whatever it may be). It is also unclear

whether design thinking is a feature of the designers proper or whether it is a reflective characterization of the scholarly field of design.

Whatever the case may be, one cannot separate the processes and acts of designing from its creators. Crucially, there is no design thinking without design *thinkers*. Unlike in the natural sciences, where a reasonable argument can be made that the purported object of study exists and behaves in accordance with a set of laws external to the investigator, in the field of design it is impossible to decouple the processes of design thinking from the social system in which it is contrived. For instance, whereas Born's rule would accurately describe the actual frequencies of quantum mechanical phenomena even if Max Born had never written it down, it is difficult to likewise understand the processes of design thinking required to produce the Pyramid at the Louvre without talking about I. M. Pei and the wider social context. Indeed, the socio-cultural factors seem integral to the process of design. As such, a social constructionist account of design thinking would not only be permissible, but also preferable to a less socially-grounded understanding. Useful though it may be for (quantitatively) understanding the nature of certain phenomena, social construction does not easily permit a coherent, unambiguous, and precise formalization. Thus, design thinking, even when it is understood within a social constructionist framework, is essentially ambiguous.

Although we have clearly delineated the categories of actor, process, and object, as well as some of the relationships between them, the literature on design thinking lacks a unifying thread. Indeed, the field has, for instance, been described as convoluted.[14] And who can be surprised? Buchanan writes,

> "[Design scholars], who increasingly come from diverse professions and academic disciplines, are not drawn together because they share a common definition of design; a common methodology, a common philosophy, or even a common set of objects to which everyone agrees that the term 'design' should be applied."[15]

It is not uncommon to see scholars discussing design thinking as a process *and* as an object *and* as a product, without clear separation between these different kinds of entities. Additionally, design scholars commonly use the term "designerly" to refer to processes of design thinking that are supposedly good or appropriate. Here, designers who engage in the process of designerly thinking, which is a qualified notion of design thinking, become objects of scholars' study. Often, this is an attempt to reflexively apply the "right" type of design thinking to the work of scholars themselves. More frequently than not, the reflexive application of designerly thinking goes unnoticed. Linking these various uses of the same term reinforces our points that the methods and practices of design scholars are pathologically ambiguous. To fully illustrate this point, we rely on Linda Laursen and Louise Hasse's[16] recent survey of the literature to organize various definitions and methodologies of design thinking and designerly thinking in the table below. Laursen and Hasse describe designerly thinking as the field of study occupied with understanding design thinking. We have faithfully retained their labels (Table 2).

Table 2. A multitude of definitions and methodologies for designerly thinking and design. A summary based on Laursen and Hasse, "The Shortcomings of Design Thinking When Compared to Designerly Thinking."

	Designerly Thinking	**(intermediate/ interdisciplinary)**	**Design Thinking/ Design**
Theoretical Approaches	1. To understand design practice and to establish itself as an independent academic discipline.[a] 2. As "creation of artefacts" and development of a rational, repeatable design methodology.[b] 3. Solving (non-rational) "wicked problems."[c] 4. "Reflective" practice.[d] 5. Problem-solving is abductive, neither deductive nor inductive.[e] 6. Practice-based approach to solving problems, making sense of things in a context, and developing new knowledge,[f] where a solution is measured based on its value in a context.[g]	Design thinking and designerly thinking have different focuses, but the two concepts are intimately related.[h]	1. A label for exporting IDEO's design processes and methods outside the context of design by people without a background in design (e.g., managers, educators).[i] 2. An iterative cycle of innovation involving proposal generation, prediction, testing, and generalization; primarily done for business purposes.[j] 3. A management theory in its own right.[k] 4. Solving wicked problems.[l] 5. Abductive reasoning as the logic of possibility,[m] including data-driven analytical thinking and intuition.[n] 6. Truth criteria is contextual meaning-making.[o]

(*Continued on next page…*)

Table 2. (*Continued*)

Methodological Approaches	1. "Reflective" practice during action and in retrospect.[p] 2. The problem and solution develop together via an iterative process,[q] leading to greater understanding of both.[r] 3. Framing and reframing as providing new directions to the designer.[s] 4. Creation of physical models, sketches, and prototypes to engage with the situation.[t] 5. Identifying the right solution[u] that is meaningful in a context[v] in light of users' values.[w] 6. Shift attention between larger and smaller tasks, and shift between analysis, synthesis, and evaluation.[x] 7. Tools used can be subdivided into those used for inquiry, identification, and creation.[y]		1. Explorative learning with wicked problems requiring iterative processes.[z]
Normative Approaches			1. Phase models consist of three to five steps (e.g., inspiration, ideation) organized in an iterative or circular fashion.[aa] 2. Perspective models underscore the importance of considering various stakeholders.[ab]
Tools			1. Very many tools being used.[ac]

a. Laursen and Hasse, "The Shortcomings of Design Thinking."

b. Herbert A. Simon, *The Science of the Artificial*, 3rd ed. (Cambridge, MA: MIT Press, 1969); John Christopher, "The State-of-the-Art in Design Methods," in *Design Methods in Architecture*, no. 6, ed. Geoffrey Broadbent and Anthony Ward (London: Lund Humphries, 1969), 193–97.

c. Horst W. J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy Sciences* 4, no. 2 (1973):155–69, DOI: https://doi.org/10.1007/BF01405730; Buchanan, "Wicked Problems in Design Thinking"; Bryan Lawson, *How Designers Think: The Design Process Demystified* (Oxford: Architectural Press, 2006); Cross, *Designerly Ways of Knowing*.

d. Donald A. Schön, *The Reflective Practitioner: How Professionals Think in Action* (New York: Basic Books, 1983).

e. Cross, *Designerly Ways of Knowing*; Lawson, *How Designers Think*; Kees Dorst, "The Core of 'Design Thinking' and Its Application," *Design Studies* 32, no. 6 (2011): 521–32, DOI: https://doi.org/10.1016/j.destud.2011.07.006; Rittel and Webber, "Dilemmas in a General Theory of Planning."

f. Buchanan, "Wicked Problems in Design Thinking"; Lawson, *How Designers Think*; Klaus Krippendorff, *The Semantic Turn: A New Foundation for Design* (New York: CRC Press/Taylor and Francis Group, 2006); Cross, *Designerly Ways of Knowing*.

g. Krippendorff, *The Semantic Turn*.

h. Schön, *The Reflective Practitioner*; Lawson, *How Designers Think*; Cross, *Designerly Ways of Knowing*; Buchanan, "Wicked Problems in Design Thinking."

i. Tom Kelley, *The Art of Innovation* (New York: Doubleday, 2001).

j. David Dunne and Roger Martin, "Design Thinking and How It Will Change Management Education: An Interview and Discussion," *Academy of Management Learning & Education* 5, no. 4 (2006): 512–23, DOI: https://doi.org/10.5465/amle.2006.23473212.

k. Richard J. Boland and Fred Collopy, eds., *Managing as Designing* (Stanford, CA: Stanford University Press, 2004); Johansson-Sköldberg et al., "Design Thinking"; Cross, *Designerly Ways of Knowing*.

l. Boland and Collopy, *Managing as Designing*; Tim Brown, "Design Thinking," Harvard Business Review (2008): 84–92, available at https://hbr.org/2008/06/design-thinking; Roger Martin, *The Design of Business: Why Design Thinking is the Next Competitive Advantage* (Harvard Business Review Press 2009), 7–11.

m. Boland and Collopy, *Managing as Designing*; Brown, "Design Thinking"; Martin, *The Design of Business*.

n. Martin, *The Design of Business*.

o. Brown, "Design Thinking"; Jeanne Liedtka and Tim Ogilvie, *Designing for Growth: A Design Thinking Toolkit for Managers* (New York: Columbia University Press, 2011), DOI: https://doi.org/10.1017/CBO9781107415324.004; Roberto Verganti, *Design-Driven Innovation: Changing the Rules of Competition by Radically Innovating What Things Mean* (Boston, MA: Harvard Business Press, 2009).

p. Schön, *The Reflective Practitioner*; Lawson, *How Designers Think; Cross, Designerly Ways of Knowing*; Buchanan, "Wicked Problems in Design Thinking."

q. Cross, *Designerly Ways of Knowing*.

r. Kees Dorst and Nigel Cross, "Creativity in the Design Process: Co-evolution of Problem-Solution," *Design Studies* 22, no. 5 (2001): 425–37, DOI: https://doi.org/10.1016/S0142-694X(01)00009-6.

s. Buchanan, "Wicked Problems in Design Thinking"; Dorst, "The Core of 'Design Thinking' and Its Application."

t. Cross, *Designerly Ways of Knowing*; Schön, *The Reflective Practitioner*.

u. Cross, *Designerly Ways of Knowing*.

v. Krippendorff, *The Semantic Turn*.

w. Dorst, "The Core of 'Design Thinking' and Its Application."

x. Ömer Akin and Chengtah Lin, "Design Protocol Data and Novel Design Decisions," *Design Studies* 16, no. 2 (1995): 211–36, DOI: https://doi.org/10.1016/0142-694X(94)00010-B.

y. Laursen and Hasse, "The Shortcomings of Design Thinking," 8, for details.

z. Brown, "Design Thinking"; Kelley, *The Art of Innovation*; Sara L. Beckman and Michael Barry, "Innovation as a Learning Process: Embedding Design Thinking," *California Management Review* 50, no. 1 (2007): 25–56, DOI: https://doi.org/10.2307/41166415.

aa. André L. Fleury, Henrique Stabile, and Marly M. de Carvalho, "An Overview of the Literature on Design Thinking: Trends and Contributions," *International Journal of Engineering Education* 32, no. 4 (2016): 1704–18, available at https://www.researchgate.net/publication/306031700.

ab. Kelley, *The Art of Innovation*; Verganti, *Design-Driven Innovation*; Liedtka and Ogilvie, *Designing for Growth*.

ac. see Fleury et al., "An Overview of the Literature on Design Thinking" for details.

Analogies with Cognitive Science

A number of recent papers published in this journal[16] rely in one way or another on cognitive science to lend legitimacy to the claims made by design scholars. Because cognitive science is a well-established and respectable discipline, it makes sense to utilize its experimental results and theories to explain the practices of designers. Moreover, given its focus on understanding the processes of problem-solving, cognitive science seems relevant for understanding design processes as grounded in human cognition and problem solving. However, it is one thing to utilize these results to explain the cognitive or affective processes designers undergo and quite another to simply import the specialized terminology to provide metaphorical or heuristic descriptions of what designers putatively do during their thinking processes. The former constitutes a legitimate type of scientific explanation, whereas the latter is simply an attempt to bootstrap unjustified claims by finding loosely connected similarities and analogies between the two disciplines. At best, scholars of design rely on cognitive scientific resources without providing reasons for thinking that the analogies between cognitive scientific results and corresponding design explananda are strong enough to support legitimate explanations. Even though analogous reasoning may sometimes count as a legitimate form of explanation, using only analogous reasoning in this context raises the worry that there are no distinctively design-centric explanations. Accordingly, it is unclear as to what exactly are the contributions that design thinkers are making in furthering our understanding of design processes.

Analogies with cognitive science fail to provide (scientific) explanations. Let us use a very simple example to illustrate this point. Psychologists found that the reaction times for comprehension are higher if people read the sentence, "push the drawer open," than if they read the sentence, "pull the drawer open."[18] That is, when the sentence they read was bodily impossible, it took them longer to understand it. There are at least two contender theories of language processing. Proponents of the first theory maintain that linguistic processing is amodal, so it can be explained without invoking embodiment. The advocates of the second theory claim that embodiment is a crucial aspect of language comprehension. The amodal thesis cannot explain the differential reaction times, but the second theory seems capable of doing so. Thus, the experimental results here favor the interpretation that language processing has something to do with embodiment. Minimally, it rules out the amodal thesis as a serious alternative. Utilizing research on embodiment, design scholars metaphorically refer to there being a "sense of fit," which the designer has in virtue of being an embodied and affective agent.[19] Verganti,[20] for instance, argues without explanation that the process of design also has linguistic aspects, which are to be understood in terms of symbolic manipulation. No doubt that in addition to being embodied and affective agents, designers are also linguistic ones! Yet, an explanation within the design framework is lacking as to why this is the case, and if it is, how it explains the design-specific phenomena that Verganti and other design scholars intend to explain. Cognitive scientists' finding that language comprehension has something to do with embodiment does not warrant that simple redescriptions (without technical details) can constitute explanations of design processes that are either (cognitive) scientific or distinctively designerly.

Generally speaking, similarity with cognitive science is taken to constitute an explanation in the field of design scholarship. Specifically, for an object of study in cognitive science that bears a similarity relation, including analogous relations, with an object in the field of design, if an explanation of the former object is provided in cognitive science, then this explanation is often imported for the object of study in design.[21] Again, the explanation is imported in the sense that mere redescriptions of the original are provided without any technical details. This type of explanation, however, is a non-sequitur, because the similarity relation does not constitute a relation of identity; in fact, reasons in favor of thinking that explanations from cognitive science distribute to the domain of design are lacking. Therefore, reliance on cognitive science constitutes neither explanations of nor justifications for the phenomena to be explained in the field of design. To be clear, we are not arguing against the use of metaphors or analogies *per se*. These play important heuristic and pedagogical functions in highlighting important similarities and differences between concepts. However, in an academic discipline aiming to understand a phenomenon, it is not enough to merely have analogical and similarity relationships. A lot more needs to be said by way of an explanation to convince a reasonably skeptical reader that the scholars are making some headway in providing general principles that explain the phenomena in question.

Another problem is that the work in cognitive science does not seem to immediately provide applicable *explanans* for the domain of design, because the former discipline is unambiguous (or, at least, has precisely formulated theses), it bears a relationship to

the physical world and to other sciences, and so on, whereas it is not even clear what the object of study in design is. Providing recommendations to designers, Lawrence Barsalou,[22] himself a respected cognitive neuroscientist, writes, "cognitive science offers scientific explanations for understanding the design process in terms of cognitive and affective mechanisms." His point is relevant to the explanations provided by design scholars insofar as the object of study in this field are human beings who think and feel. However, the question then is, "What are the scientific or academic contributions of design scholars?" It is not that, as far as we are aware, the scholars of design have carved out a domain of study that is distinctively designerly, or that in design thinking there are features that cannot be explained by appeal to cognitive science.[23] In fact, the appeal to cognitive science is justified only if (i) the object of study of design scholars is relegated to that of cognitive science, or (ii) the object of study is reduced to cognitive sciences (and, possibly, to its most fundamental constitutive discipline).

If choice (i) is taken, then it would be conceded that though there is something distinctive about design that needs explanation, we (somehow) care only about those aspects of design that cognitive sciences can appropriately explain. As we mentioned above, this is akin to saying that the object of study of design scholars is explicable only as much as the object of study is a human agent capable of thinking and emoting. By contrast, if option (ii) is taken, then there is nothing left for the scholars of design to explain. A reductionist approach implies that the object of study is no longer available for design-centric explanation.[24] However, for a reductionist approach to be palatable, design scholars would need to permit the reduction of "designerly processes" to the domain of cognitive science, whose own explananda may itself (ideally) reduce to the physical sciences. Problematically, it does not seem to us that this is a viable notion, as part of the underlying assumptions behind design thinking is a rejection of strong ontological reductionism, if not a rejection of ontological materialism itself. Consequently, such an approach is a non-starter for these scholars.

So far, option (ii) seems unacceptable but option (i) has some merit, since the *practices* of design scholars suggest that appeal to cognitive science is acceptable. While there is something distinctive about design's object(s) of study, and thus, it is in need of proper explication, the state of scholarly work is not up to the task of providing such explanations. Cognitive science can only go so far in explaining the object of study of design. Those features of design processes that are taken to be independent of the underlying cognitive and socio-cognitive effects deserve consideration that is distinctively designerly.[25] Even in cases where cognitive sciences can in principle explain aspects of the design processes, such explanations (which design scholars attempt to provide) cannot be merely metaphorical and heuristic. More importantly, when cognitive science does not go far enough – in other words, when it does not fully explain everything that the scholars of design intend to explain – the task is left to these scholars to provide robust and precise explanations grounded in falsifiable empirical evidence.

Standards of Evidence and Justification

Recent scholarship in design relies greatly on cognitive science both for its theoretical framework and for its experimental justification. We now briefly address the standards of justification used in the field of design and the evidence presented in favor of the claims being advanced. We conclude that the standards of justification which the field holds itself to are completely inadequate for considering it a scientific discipline.

It is well-recognized by philosophers of science, and indeed by most practicing scientists, that for a theoretical claim to be acceptable within the framework of modern science, it must be falsifiable:[26] it must, in other words, in principle be possible to refute it.[27] A standard method by which a theory may be refuted is by finding convincing (theoretical or empirical) evidence to the contrary. Ordinarily, experimental evidence is impugned if others follow the same experimental procedures but fail to replicate it, or if the replicated experiment produces results that are inconsistent with those of the original experiment. Empirical evidence is used to adjudicate between competing models and theories. Ideally, a number of experimental results favor one model in such a way that alternative explanations are ruled out, in the sense that they fail to explain the data or the data are inconsistent with the theoretical predictions. The important point is that empirical evidence serves as the basis upon which theoretical claims are judged.[28]

Justifications of theoretical propositions based on experimentation rely, in one way or another, on inductive inferences, which are in principle fallible. Because the nomological domain is finite and inductive generalizations are about this domain, these generalizations are fallible because there could in principle be an evidential instance that counts against

the generalization. However, philosophers of science recognize that, fallible though they may be, inductive generalizations provide reasonable, and perhaps even probabilistic, propositions about the world.[29] There is agreement about one thing: the degree to which one is justified in making inductive generalizations crucially depends on the number of evidential instances in support of that generalization. The higher the number of evidential instances in favor of the generalization, the more the agent is justified in believing it. Let us evaluate the implications of these points for the use of anecdotal evidence in the field of design.

Before we evaluate the use of anecdotal evidence in the field of design, recall the distinction between the practice of design and the scholarly study of design thinking. The former, as a pragmatically oriented practice, has implicit notions of success and failure that depend on the satisfaction of the consumer. In this capacity, the measure of the success of a design can be understood in terms of anecdotes. Moreover, the replication and proliferation of some design products may also be justified by these anecdotal instances. For instance, positive reviews based on personal experience may provide justifications for designers to continue producing the product. However, our contentions apply only insofar as we are concerned with the scholarly study of design. It is in this latter context that, as we shall argue, the usage of anecdotal evidence is inadmissible.

Anecdotal evidence is empirical observation or experiential interpretation, which may be exogenous or endogenous, that provides very weak justification for inductive generalizations in part due to the scarce number of non-repeatable instances. Therefore, anecdotal evidence does not provide grounds for reasonable inductive generalizations, as practically most other evidential instances would count against such a generalization. Moreover, anecdotal evidence is often *subjective*, taking the form of either direct experience or reporting others' experiences. Conducting a study of anecdotal evidence in public scientific controversies, Alfred Moore and Jack Stilgoe write, "anecdotal evidence comes to be accepted (albeit in different ways) by the main actors as an *epistemic* category, yet that [sic] it is multidimensional, open to interpretation as *subjective* reports."[30] They further write that "anecdotes and anecdotal evidence are clearly *individual*, and thus lend themselves to reconstruction in terms of 'subjective' versus 'objective' modes of thought."[31] Consequently, it is impossible to falsify anecdotal evidence, because to do so is to conclusively refute a subjective experience occurring either in a single moment or over a span of time. Because anecdotal evidence is unfalsifiable, it cannot be used to support inductive inferences, and thus, it cannot be admitted in the sciences.

Within the study of design thinking, it is not uncommon to find claims being justified with anecdotal evidence.[32] Anecdotal evidence may be garnered by observing the process of a single design project and/or by looking at a single team of designers working on a problem. Some design scholars[33] even go so far as to present fictional scenarios (complete with characters) as legitimate evidence in favor of certain claims.[34] We can see that design scholars in fact *do* use anecdotal evidence, and other even more pathologically flawed forms of evidence as providing justificatory grounds for their explanations.

It is undoubtedly true that the phenomenological dimension is crucial for studying and experiencing design. Thus, there is a *prima facie* reason for admitting anecdotal evidence to adjudicate between different models, and any empirical evidence in this discipline would necessarily be subjective to a certain degree. The evidence-centric problems nevertheless abound even if anecdotal evidence is admitted. First, literature in cognitive sciences tells us that memories are unreliable. In particular, when memories are retrieved, they are amenable to modification due to so-called "top-down" cognitive effects. After being impacted by these effects, the re-encoded (or reconsolidated) memories in the hippocampus are often very different from those that were initially encoded.[35] Accordingly, if reconsolidated memories are used as evidence to support a certain model of designerly thinking, and if this model was the top-down cognitive effect impacting the memory, then the structure of this reasoning process constitutes a case of circular reasoning. More concretely, if a design scholar supports a particular model as providing satisfactory explanations of some designerly phenomena, and in order to highlight to his colleagues the intuitive appeal of the model, he recalls the particular anecdote in question (thus, impacting the memory, as explained), and later, if he uses the (affected) anecdotal evidence in support of the model, then the argument is circular. In short, the model affects the memory (anecdote) and the memory supports the model.

Second, the effects of various heuristics that subjects fall prey to are well-documented in the psychological literature. We will use the availability heuristic as a representative case to demonstrate how anecdotal evidence can be impugned. Our explanation, though, is generalizable, namely, anecdotal evidence is negatively impacted by other types of heuristics as well. Roughly, the availability heuristic is the idea

that if certain information is more easily recalled, then the subject judges it to have higher probability.[36] Now, in debating the merits and demerits of a model, design scholars will recall certain anecdotes – experiences, for example – more easily than they will recall others. Since they would be influenced by the models they take to be more plausible, it is unsurprising that they would more easily find anecdotal evidence supporting the model than evidence contradicting it. Given the availability heuristic, it would appear that there are a great many evidential instances favoring the model. Thus, a large amount of evidence in support of the model will be recalled, and only a small amount of evidence (if any) against the model will be recalled.[37] Given these considerations, skepticism about anecdotal evidence is our best bet.

Lastly, people can simply make up anecdotes to support their theories! There is no way of judging these anecdotes, as the only judge of an experience is the person having it. Consequently, there could in principle always be counter and favoring evidence with respect to a model, wherever there is enough ingenuity and unscrupulousness on the part of certain people! Nevertheless, the claims of unfalsifiability and research from memory and heuristics serve as the best reasons for rejecting anecdotal evidence as reliable grounds for believing in inductive generalizations. Even if design scholars reject falsificationism on philosophical grounds, research in cognitive science cannot be ignored, especially given that design scholars intimately rely on this discipline.

To our knowledge, anecdotal evidence and secondary evidence from other fields constitute the main forms of support for claims made by design scholars. We have considered why the former type of evidence is problematic, and we have also considered what is problematic with the latter type. Now, a few comments summarizing the points about the structure of justification are in order. First, (unfalsifiable) anecdotal evidence is an insufficient basis upon which to make inductive generalizations. Second, the use of anecdotal evidence, which intimately depends on human memory, to support theories gives rise to viciously circular reasoning. The theory fixes its evidence, which then justifies the theory in question. Third, reliance on cognitive science works only in limited cases, namely those in which the object of study are the cognitive and affective dimensions of designers. Vague relations of similarities, having a sense that two ideas are related, or utilization of terminology in a non-technical fashion do not give sufficient grounds for considering a proposition justified. It is not enough to say that cognitive scientists talk about embodiment and affect, and since these terms also have something to do with the process of design, the two concepts are applicable to the latter domain. We therefore normatively suggest that not only should design scholars apply (if at all) the concepts of cognitive science with the same degree of rigor with which they are applied in the original discipline, these scholars also need to provide explanations, justifications, and evidence that are distinctively designerly if we are to consider the discipline unique in its own right. Additionally, as anecdotal evidence fails to be sufficient for any sort of scientific explanation, and it appears as though anecdotes are one of the only modes of empirical evidence that design scholars use, we suggest that the community, as it were, rebrand itself to orient more towards a social studies discipline, such as STS or sociology of science, that is concerned with studying the humanistic and social aspects of how various forms of knowledge, methods, and reasoning-processes develop and manifest themselves in the world. These fields have well-established methodologies that grapple with problems similar to those faced by design scholars. Such an approach would at least provide fruitful directions for future research. The current state of affairs in design, however, is misaligned with the aims of STS or sociology of science. As it currently stands, the field at times appears to be pseudoscientific.

Conclusions

It is not an exaggeration to exhort design scholars to develop a more robust and precise agenda for their field. First, it needs to be made clear whether they construe their field as a particularly rich and unique extension of cognitive science, or if it is to be subsumed under the social sciences with close ties to STS. On the one hand, if they consider it an extension of cognitive science, then the following non-exhaustive list of minimal criteria must be satisfied:

(1) The object of study for design scholars needs to be clearly articulated by, for instance, thoroughly and clearly explicating the underlying principles of creative processes that guide design thinking, as well as what constitutes an instance of design thinking as a cognitive process.

(2) Concepts ought to be defined rigorously and applied consistently; metaphorical and heuristic usage of terminology, while useful in providing readers with a general *sense* of the idea, is unacceptable in a mature field of science. The scholars in this field need to likewise

precisely define and consistently apply the definitions, which no doubt may be used only tentatively, that they develop. The starting point may be to provide a definition of design[38] and decide whether it is a natural kind.

(3) Once such a clear, precise, and detailed framework is established, design scholars must identify how this framework is situated with respect to standard ideas from cognitive science. For instance, is the design process to be understood within a generally materialistic framework? How crucial of a role does embodiment play here? Is syntactic processing explanatorily relevant? What is the role of affect?

(4) Empirical evidence that is testable by others, including those in other fields, needs to be provided in support of claims. Anecdotes,[39] fictional characters,[40] or first-person[41] accounts do not count as falsifiable evidence, and so they cannot be used in a scientific field, though the phenomenological dimension of design is no doubt important. Further, the evidence can, and even should, draw upon other disciplines in the sense that primary research can be done by scholars in this field using reliable methodologies from other fields, such as using fMRI to study the cognitive neuroscientific mechanisms of creative processes. Of course, this does not preclude the possibility of having exclusively design-centric evidence, whatever that may look like—but at least for the short run, reliance on the methodologies of established scientific disciplines would be a commendable starting point. Indeed, it would be excellent to provide an outline of what a distinctively design experimental methodology may look like.

On the other hand, if scholars choose to characterize their discipline as a social scientific pursuit, (as we suggest they ought), then the discipline may be better served by considering the sociological, structural, affective, and phenomenological features of the consumption and production of design products. One of the crucial parts of design is the transformative experience a consumer may have as a result of being in a creatively designed place. These may be important in understanding the role of design in society, including how consumers create problems requiring design solutions. Furthermore, studying what makes a particular design more effective than another and quantifying the degree of success of a design solution, investigating the perceptions of various designs by customers (in different cultures), and understanding design processes through interdisciplinary lenses (for example, design within resource constraints) are interesting questions deserving close scrutiny. With this new territory, the field would, of course, require a new set of methodologies motivated by those of the social sciences. Although these methodologies may need to be altered to accommodate the unique features of design as a discipline, there still remains a necessary standard of explanation and empirical evidence that the current framework would need to adjust to. However, if such social scientific methodologies were to be adopted, one could be much more confident in the various claims made by design scholars, which presently are little more than conjecture, on the grounds that the social sciences have established methodologies that deal with issues such as lack of empirical basis for theoretical claims. Needless to say, this would need to be applied by keeping design's uniqueness in mind.

As previously mentioned, Cross thought of design as being distinct from the arts and sciences.[42] However, it is important to remember that the *discipline* of design scholarship is a distinct category from that of design proper (design scholars are *not* designers, unless there exists an accidental intersection of actors), and so it is not outlandish to suppose that design scholarship may indeed closely resemble some form of pre-existing academic discipline, be it one of scientific nature (like cognitive science), or one that is more sociologically oriented (such as STS). As we have argued, the discipline of design does not have a well-delineated agenda as to what its object of study is, what the employed methodologies are, and so forth. Hence, unless design scholars can define their discipline in a way that distinguishes it from the arts and social sciences, our suggestion would be to stick closer to well-delineated paths (of artistic and scientific pursuits) and define the discipline according to the interests and abilities of those engaged with this field. Once again, as a cautionary note, we are *not* criticizing the designers proper, the consumers, businesses, or other stakeholders; our criticism is laid against the academics that write books, publish in journals, attend conferences, and lack a unifying basis of thought. Systems of academic research are allowed to become extremely sophisticated and intricate. However, if they lack a consistent set of methods and practices, if they have low standards for justification, and if the underlying framework of their field is highly ambiguous and only partially developed, more advanced, complicated theoretical hypotheses are no more than castles in the sky.

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6 Ludwik Fleck, *Genesis and Development of a Scientific Fact*, ed. Thaddeus J. Trenn and Robert K. Merton, trans. Fred Bradley and Thaddeus J. Trenn (Chicago: University of Chicago Press, 2008); Maria Baghramian and J. Adam Carter, "Relativism," in *Stanford Encyclopedia of Philosophy*, ed. Edward N. Zalta (Stanford, CA: Standford University, 2015), available at https://plato.stanford.edu/entries/relativism/.

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9 Simon Blackburn, *On Truth* (Oxford: Oxford University Press, 2018).

10 Ibid.

11 Yao-Tsung Ko et al., "Modelling a Contradiction-Oriented Design Approach for Innovative Product Design," in *Proceedings of the Institution of Mechanical Engineers, Part B: Journal of Engineering Manufacture* 229, no. 1_suppl (2015): 199–211, DOI: https://doi.org/10.1177/0954405414564810.

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14 Lindgaard and Wesselius, "Once More, with Feeling."

15 Buchanan, "Wicked Problems in Design Thinking," 14.

16 Linda Nhu Laursen and Louise Møller Haase, "The Shortcomings of Design Thinking When Compared to Designerly Thinking," *The Design Journal* 22, no. 6 (2019): 813–32, https://doi.org/10.1080/14606925.2019.1652531.

17 Lindgaard and Wesselius, "Once More, with Feeling"; Antle, "Making Sense of Design Thinking"; Goldschmidt, "Design Thinking"; Diethelm, "Embodied Design Thinking."

18 Max M. Louwerse and Patrick Jeuniaux, "The Linguistic and Embodied Nature of Conceptual Processing," *Cognition* 114, no. 1 (2010): 96–104, DOI: https://doi.org/10.1016/j.cognition.2009.09.002; Barbara F.M. Marino et al., "Language Sensorimotor Specificity Modulates the Motor System," *Cortex* 48, no. 7 (2012): 849–56, DOI: https://doi.org/10.1016/j.cortex.2010.12.003.

19 Much of this work stems from Christopher Alexander's *Notes on the Synthesis of Form*, wherein the notion of "goodness of fit" is originally developed, and which many take to be a fundamental feature of design thinking. Christopher Alexander, *Notes on the Synthesis of Form* (Cambridge, MA: Harvard University Press, 1964), 15–16; Karin Lindgaard, "Nature, Consciousness and Feeling: The Therapeutic Potential of Process Philosophy" (PhD dissertation, Swinburne University of Technology, 2009); Lindgaard and Wesselius, "Once More, with Feeling," 88; Roberto Verganti, *Overcrowded: Designing Meaningful Products in a World Awash with Ideas* (Cambridge, MA: MIT Press, 2017).

20 Verganti, *Overcrowded.*

21 Chiu-Shui Chan, *Design Cognition: Cognitive Science in Design* (Beijing, China: China Architecture and Building Press, 2008).

22 Barsalou, "Define Design Thinking," 102.

23 By "explain," we do *not* mean the heuristic and metaphorical use of the same words, which the discipline of design currently embodies, but rather a proper explanation appropriately connecting the explananda to explanans.

24 A third approach is eliminativism, according to which the putative object of study of design scholars is altogether non-existent, and so references to designerly thinking or designerly processes are completely false. On this view, the appropriate attitude is to eliminate all such references from scientific theorizing. The scholars of design would understandably want to resist a thesis as strong as this.

25 We do not know what these independent features are, but whatever they turn out to be, a clear explanation of what they are and how they are independent of everything else in the sciences needs to be provided.

26 Karl Raimund Popper, *The Logic of Scientific Discovery* (London: Routledge, 2002). Robert Nola and Howard Sankey, "Popper, Lakatos and Scientific Method," in *Theories of Scientific Method: An Introduction* (Santa Fe, NM: Acumen Publishing, 2007), 252–84, DOI: https://doi.org/10.1017/UPO9781844653881.011.

27 Falsification is now understood to be a vast over-simplification of the problem of scientific demarcation. However, falsifiability in its multifarious forms still plays a central role in the sciences. Importantly, falsifiability is a very minimal notion; all it asks is that the proposition being advanced should in principle be refutable.

28 The cases of underdetermination are problematic, because here the empirical results are explained by a number of competing explanations.

29 Robert Nola and Howard Sankey, "Some Justifications of Induction," in *Theories of Scientific Method: An Introduction* (Santa Fe, NM: Acumen Publishing, 2007), 143–63.

30 Alfred Moore and Jack Stilgoe, "Experts and Anecdotes: The Role of 'Anecdotal Evidence' in Public Scientific Controversies," *Science, Technology, & Human Values* 34, no. 5 (2009): 654, DOI: https://doi.org/10.1177/0162243908329382, our emphasis.

31 Ibid., 656; our emphasis.

32 For instance, see Antle, "Making Sense of Design Thinking," 95.

33 For instance, see Diethelm, "Embodied Design Thinking."

34 To be clear, the usage of fictional characters here is *not* in the form of thought experiments. In this instance, fictional characters are used to *play the role* of hypothetical actors carrying out *hypothetical* actions, and then supposing that this then constitutes anecdotal evidence for the practices of non-hypothetical actors, who may or may not in fact act in that way.

35 Richard D. Lane et al., "Memory Reconsolidation, Emotional Arousal, and the Process of Change in Psychotherapy: New Insights from Brain Science," *The Behavioral and Brain Sciences* 38 (2015): e1, DOI: https://doi.org/10.1017/S0140525X14000041.

36 Amos Tversky and Daniel Kahneman, "Availability: A Heuristic for Judging Frequency and Probability," *Cognitive Psychology* 5, no. 2 (1973): 207–32, DOI: https://doi.org/10.1016/0010-0285(73)90033-9.

37 As to how the availability heuristic would influence the recall of anecdotal evidence in favor of or against alternative models is an open question.

38 see Barsalou, "Define Design Thinking" for suggestions.

39 Antle, "Making Sense of Design Thinking."

40 Diethelm, "Embodied Design Thinking."

41 Michael A. Simon, "Explaining Behavior Skinner's Way," *Behavioral and Brain Sciences* 7, no. 4 (1984): 646–47, DOI: https://doi.org/10.1017/S0140525X00027886.

42 Cross, *Designerly Ways of Knowing*.

The Language of Design and the Design of Language

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Abstract This short essay is a commentary on the article by Michael Lissack, and it provides a point of view. In this point of view it is seen that while one can admit that the channel capacity for human observers is limited, it is exactly this limitation that has led to the emergence of language and the use of language to transcend these very limitations. The problems of the present day can be solved by each observer/participant attending to design. It is in the design and use of language that individuality and balance can emerge.

Keywords Design; Dasein; cognition; observer; reflexivity; cybernetics

Let me begin by quoting the very end of Michael Lissack's article, Part 1:

> "This Part 1 has introduced the reader to the ideas of limited cognitive capacity, the law of requisite variety, the least action principle, and the contrast between representations and compressions. Part 2 will focus on how those concepts come together in our understanding toolkit. In Part 2, the reader will learn about 5 kinds of tools: models, choosing what we attend to, selecting among adjacent possibles, priming the context, and highlighting/suppressing questioning. The emphasis in part 2 is on agency and choice – we choose those aspects of the world we attend to and the frames and backgrounds we apply in then making sense of the items we chose. Understanding is a product of choices that are forced upon us as we seek to overcome the mismatch between the relentlessly rich, interwoven complexity of the world and our minds' limited ability to cope with it all. When we recognize that we can actively choose rather than merely accept what appears to be a pre-given conclusion, we open the door to agency. And agency opens our understanding to the myriad possibilities of design."[1]

Michael emphasizes that at any given time we, as observers and cognizers, have a limited channel of access to the complex world in which we live. He points out our inability to handle large amounts of information and our consequent reliance on summaries, beliefs, and simplifications. He points out that a cybernetic point of view, with awareness of our own role in shaping our thoughts and perceptions and actions, will result in a more effective relationship with the complex world. In this regard, he recommends that we each become the designers of our relationships with the world. The relationship of a designer is a relationship of a person with his intent to create (that which he designs).[2] A designer must be willing to question implicit rules for himself and society. He must have a sufficiently complex relationship with his creative material (requisite variety) to allow the creativity to take place. He must find the paths of most efficient action for his being in the world. He must not assume that the world is independent of how he acts upon it. Indeed, in the first place – the beginning place, the beginning of the music, the aborning of a human, the inception of a design – the world and how we act upon it are indistinguishable. And it is only through the multitude of distinctions drawn that an apparent separate world emerges.