Undeniably, the biggest barriers to implementation can be found in the social, political and economic frameworks: changes in the political and funding climate have blown our ambulance project off course – temporarily, we hope.

Advice from Norman and Stappers that designers should avert their gaze from the sprawling imperfections of big systems, and "'muddle through'"[4] by taking small, modular steps rather than big leaps of creative faith is probably sensible. But it goes against the grain of more than 50 years of project-based design education in which designers have been taught to think big and bold outside the constraints of any system, and to learn through trying, making, and failing.

The gap between the demands of today's complex systems and how most trained, hyper-focusing designers see the world is a chasm that even those most precise – and welcome – categorizations of DesignX might struggle to bridge.

1 Don A. Norman and Pieter Jan Stappers, "DesignX: Complex Sociotechnical Systems," *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 2 (Winter 2015): 83–106.

2 For more information, see http://www.smartambulanceproject.eu/wp-content/uploads/2015/02/Redesigning_the_Ambulance_Lo-Res.pdf.

3 Norman and Stappers, "DesignX."

4 Charles E. Lindblom, "The Science of 'Muddling Through'," *Public Administration Review* 19, no. 2 (1959): 79–88, quoted in Norman and Stappers, "DesignX.".

Designing for X: The Challenge of Complex Socio-X Systems

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We might observe across the social disciplines that the complexity of modern existence has led to calls for more systemic and design-led approaches to deal with unmanageable complexity. While it has been more than 40 years since the publication of Rittel and Weber's *Dilemmas in a General Theory of Planning*,[1] it appears that it has taken until well into the 21st century for the strategy of designing for wicked problems to have shaped courses of collective action. The exploration of DesignX problems redirects the project toward defining and educating for advanced practices capable of validating design for complex sociotechnical systems.

Perhaps this has come about from acknowledging a manifested breakdown in the ability of conventional management and policy to enact effective and predictable outcomes consistent with societal goals – in other words, our practices have become too complex to redesign them effectively for what might better serve human social needs. Bruno Latour's recent call to embrace validated modernist institutions[2] suggests that cooperation and collaboration across disciplines might be crucial at this point in history. After all, the sciences and engineering have demonstrated effective approaches to deal with significant technical problems, so we might trust the hard sciences to deal with global crises, whether climate change, economic development, geopolitical policy, or food supply systems.

Such is the nature of DesignX problems – or perhaps emerging DesignX situations – that we can examine through the lens of the DesignX manifesto. As one of the case presenters in the Shanghai meeting described by Norman and Stappers, I might acknowledge that the inaugural discussion was not only composed of a group of true believers, but a notional starting point, a grounding of perspectives in a continuing dialectic. The sharing of complex sociotechnical systems as design cases was not novel, as the material could have been presented as relevant at many different symposia; neither was the call to discuss and engage questions of appropriate design evidence, or the identity of "systems," or the hows and whys of systemics in complex design problems. The difference in the DesignX discourse was an intent toward achieving solidarity – if not consensus – that as design educators, "we must do something." The case studies and discussions yielded the demonstration that the fields and models of design remain richly diverse, and we have many models and methods perhaps suitable for addressing societal and sociotechnical concerns. However, we still have very little deeply-shared vocabulary with which to address the different types of problems, their systematic relationships – within and across system types, their functional elements, and their human behavioral relationships. Securing some agreement toward a common taxonomy will make a difference in inter-disciplinary communication, and this is one aspect of evidence-oriented design that would help across the range of design practices.

In this issue, the article "DesignX: Complex Sociotechnical Systems"[3] presents nine issues or dynamics that are proposed as characteristic in sociotechnical problems. I might simplify them as follows:

Social and psychological factors of system participants and designers:

- The role of psychological factors in system design
- The role of cognitive biases and human uses needs that ignore systemic behaviors
- The need to integrate multiple disciplines and perspectives in sociotechnical design
- Design dilemmas in the conflicts of incompatible constraints

Technical and systemic factors within STS problems:

- Interconnected (but largely concealed) internal functions
- Nonlinear causality and multi-casual feedback processes
- Undisclosed delays, lags, and latencies in feedback and control
- Irreconcilable scales of time and space
- Dynamic operational changes

I repeat these because it's worth rethinking their meaning in different expressions. Another reader might configure them in yet different terms, and determine whether they fit their cases, or perhaps remain incomplete until other general applications are proposed and tested across cases. These nine are consistent with the sociotechnical systems (STS) literature, in general, but we might also recognize other factors, perhaps significant, that might help to assert and test, even if such factors are not generalizable across all STS.

Designing for Complex Social Domains

One of the facilities gained with domain expertise is the ability to distinguish important features that contribute to a domain's overall complexity, and not just the systemic or operational complexity that we might analyze in an engineering exercise, for example. I believe the DesignX construct – if meaningful across design disciplines at all – requires us to reimagine how we might design within domains, rather than apply toolkits of advanced design skills across them. A constructivist epistemology – which we might also claim as consistent with designing for these systemic factors – further requires us to develop categories *within* these domains as appropriate in the domains as worlds constructed by their everyday participants. New systemic design approaches are emerging within healthcare delivery, bioregional sustainability, business models and services, food and shelter security, corporate and civic governance, and several others. I mention these in particular because each of these domains can be assessed as complex, publicly accessible, and yet contained as a system governed by its own rules and legacies.

When we consider interactive work systems for productive goals, the focal perspective adopted by designers is the sociotechnical, endorsed and developed in cognitive engineering, technological work studies, and significantly in healthcare informatics.[4] The sociotechnical perspective is not widely embraced in design education, and even its treatment in human factors programs can be charitably indicated as variable.

More significantly, each of these domains not only contains sociotechnical systems – as we have noted as relevant to DesignX – but can be identified as larger, more socially complex domains represented as *socioecological* systems. The rich body of work from the Tavistock legacy developed across three perspectives, or levels, of social systems, designated the socioecological, sociotechnical, and sociopsychological.[5]

Within most domains or organizations with complex STS problems, we can identify complex socioecological systems wherein a collective social system interacts with its environment. When expanding the problem of mental health – to use my DesignX case for example – or even radiation oncology, the healthcare context implicates its environment as the source of the disease conditions: the family, lifestyle, and social determinants of disease, as well as the construction of "patients" in a healthcare system.

Consider the additional complexity factors we might face as systemic designers choosing to work with the socioecological system as well as the technical work practices. We can find, study, and design for the social ecologies associated with the production of health in a community. The social determinants of health arise from a socioecological viewpoint, and this view helps reveal the mutually determining factors that enable health outcomes from a mental health intervention or cancer care.

The literatures and research methods between these "socio-*x*" perspectives are quite different. Because it's unlikely that graduate design education will sufficiently touch on these perspectives and their case studies, we risk ignorance of this extraordinary, developed knowledge – possibly dimly reinventing their models when faced with correlated insights, yet not benefitting from appropriating the wisdom of 60-plus years of deep experience in these systemic perspectives.

However, we might ask: if "we" across the design disciplines are not designing for complex socio-technical systems, then who is? Are we ignoring these problems to some extent from conflict with aesthetic tastes, or because actually resolving these problems resists the rapid satisfaction of creative "design thinking?" Or, are we shunning involvement with the depth of complexity, a lengthy commitment to a problem, and the inherent risks of bad design decisions? We might start finding in these critical problems the moral equivalent of infrastructure – we have to improve design for technological integration, because our lives and social ecologies depend on it.

Designing a DesignX Theory of Change

While a popular principle of complexity thinking is that small changes at the right place can make outsized differences, such theories of change often seem wishful. In modern societies, the interconnectedness of governance and funding with information technology and legacy systems means, more likely, that complex systems become densely, internally connected, and so resist either planned or designed interventions. Because of complex networks, we have an Internet that prefers monopolies to interesting innovations. In the United States, we have public policies – such as cold war era military base proliferation and subsidies of oil majors – that continue apparently without guidance from any citizens. As social systems planners warned 50 years ago, we now have completely interconnected issues, mutually locked-in and path dependent. These are not requisite conditions for organization-centered change, but require multiple stakeholders committed to future betterment. As Flach[6] notes in his endorsement of an incrementalist theory of change, we might explore a shift from "resolving complexity" and transformational programs to skills of coping in the face of the unreality of control. Such an approach recalls Latour's[7] entreaty for design as a modest, self-aware process of coping with "matters of concern" as opposed to the normative "matters of fact" of desirable outcomes.

In practical design terms, we must also consider the problem of *initial conditions* of both the system and the human designers, another factor that cuts across all three sets in the framework. The initial brief, sponsoring team, and system owners significantly influence the way a design team approaches the goals for change and intervention. While we might wish to believe that, as designers, we can invoke the requisite magic of independent thinking and reframing;[8] but when given a complex problem sponsors care about, we find ways to satisfice something of the concern. We muddle through more often than heroically reframe with the perfect framing proposal. As designers we are almost never experts in a domain, and our own initial conditions might be creatively speculative, but weakly informed.

Consider that in policy and organizational domains, social systems associated with institutions sometimes involve many different levels of authority responsible for interdependent decisions. Therefore, we almost never have the ability to "design the change" directly, but are constrained to negotiating the scope and brief of our initial sponsors. The most powerful knowledge for changing any system – and the minds of sponsors – lies with its deep users and stakeholders. These participants must be identified and often discovered over time, another incremental process that challenges the ability to reframe an STS design project. Yet, even when new stakeholders are discovered, we are biased toward an initial investment of sunk cost time and learning that can establish a path dependency, so initial conditions and framing iterations remain critical tools in the systemic design approach.

Perhaps then much of the fashionable rhetoric about transformational system change is hubris and wishful optimism expressed by inexperienced designers that have not directly witnessed cascading failures in products, organizations, or businesses. After all, system failures follow the same rules and factors as indicated in the five technical concerns in the list.[9] We may not have seen sufficient history to imagine and simulate the kinds of human connections that fail to obey system prototypes or expected rules. Designers rarely have to live with the consequences of their proposals, as has been seen in the wishful thinking of innovative design proposals for bottom of the pyramid problems such as clean water supplies and clean cook stoves in subsistence living conditions.

Norman and Stappers are on the right track by recommending a revaluation of Lindblom's incrementalism. Long held in disregard as the enemy of innovation, the argument against muddling through falls apart when we consider the meaning of "successful design" in high complexity. These domains have less demand for disruptive transformation – a demand that often boils down to commercial market disruption to return fabulous wealth to innovation investors. Therefore, systemic design approaches might develop rather incremental change approaches, with stakeholders "discovered" over longer cycles than in contained STS, as there might be significant knowledge and experience across stakeholders inaccessible to the design team initially. Careful analysis and an iterative learning approach to design yield greater team understanding, reducing the probability of a Type I, false positive error – as when design teams rush into action, and believe an initial successful prototype demonstrates transformation.

Within complex domains, we also see significant legacy effects and path dependency for incremental or discontinuous design approaches. Technical and technology regimes from different eras and applications are extremely complicated and highly constrained; these are problematics that can be more time consuming than the "merely" complex. A chief constraint in most established information systems is the volume and complexity of legacy software, databases, and expensive custom interfaces between systems developed over time by long-gone programmers and sometimes archaic languages. Many software modules are black boxes that cannot be modified effectively without complete transformation of the system.[10]

Conclusions

Norman and Stappers reach optimistic conclusions that help move discourse beyond problematizing and into design action. Their conclusions suggest that an incrementalist approach to designing for complex work practices that implicate a range of stakeholders can be constructed in a modular way to yield successful progress, and enable stakeholder participation and effective design management. While there are risks of under conceptualizing the social system under inquiry, some scholars[11] would argue that stakeholders can never cognitively appreciate the system sufficiently under any conditions.

With respect to their conclusion to pay considerable attention to social, cultural, and political issues with complex systems design, I address the proposal to evaluate complex social interdependencies as socio-ecological systems. This perspective deserves its own methodological and design discussion separately from the DesignX treatment of sociotechnical systems. I would recommend the expansion of DesignX to consider the range of socio-*x* problems that DesignX might entail. While we might consider all of these domains or problem types as opportunities for systemic design, I would maintain systemic design as a field of advanced design methodologies applicable to all types of complex system problems, across social and ecological domains. The position of DesignX seems resonant as a problematic of system challenges for which design theory, practice, and pedagogy remain currently insufficient to the task. In this regard, I consider DesignX a challenge trade space for resolution of the most modern, that calls for a more deliberative, systematic, and scientifically-informed multidisciplinary challenge.

1 Horst W.J. Rittel and Melvin M. Webber, "Dilemmas in a General Theory of Planning," *Policy sciences* 4, no. 2 (1973): 155–69.

2 Bruno Latour, *An Inquiry into Modes of Existence* (Cambridge, Mass.: Harvard University Press, 2013).

3 Don A. Norman and Pieter Jan Stappers, "DesignX: Complex Sociotechnical Systems," *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 2 (2015): 83–106.

4 See, by way of comparison, Joan S. Ash, Marc Berg, and Enrico Coiera, "Some Unintended Consequences of Information Technology in Health Care: The Nature of Patient Care Information System-Related Errors," *Journal of the American Medical Informatics Association* 11, no. 2 (2004): 104–12; Michael I. Harrison, Ross Koppel, and Shirly Bar-Lev, "Unintended Consequences of Information Technologies in Health Care—An Interactive Sociotechnical Analysis," *Journal of the American medical informatics Association* 14, no. 5 (2007): 542–49; Andre Kushniruk and Paul Turner, "Who's Users? Participation and Empowerment in Socio-Technical Approaches to Health IT Developments," in *International Perspectives in Health Informatics: Information Technology and Communications in Health* (*ITCH*), ed. Elizabeth M. Borycki et al. (Clifton, VA: IOS Press, 2011), 280–85; Christopher Nemeth et al., "Minding the Gaps: Creating Resilience in Healthcare," *Advances in Patient Safety: New Directions and Alternative Approaches* 3 (2008): 1–13.

5 For more information, see http://www.tavinstitute.org.

6 John M. Flach, "Complexity: Learning to Muddle Through," *Cognition, Technology & Work* 14, no. 3 (2012): 187–97.

7 Bruno Latour, "A Cautious Prometheus? A Few Steps Toward a Philosophy of Design (with Special Attention to Peter Sloterdijk)," in *Proceedings of the 2008 Annual International Conference of the Design History Society* (*UK*), ed. Fiona Hackney, Jonathan Glynne, and Viv Minton (Falmouth, Cornwall: University College Falmouth, 2008), 2–10.

8 Kees Dorst, "Frame Creation and Design in the Expanded Field," *She Ji: The Journal of Design, Economics, and Innovation* 1, no. 1 (2015): 22–33.

9 Takafumi Nakamura and Kyoichi Kijima, *System of System Failure: Meta Methodology to Prevent System Failures* (Rijeka, Croatia: INTECH Open Access Publisher, 2012).

10 An extreme case might be the US air traffic control system, of which several major programs failed to incrementally revise in the 1980's and 1990's.

11 John N. Warfield, "Twenty Laws of Complexity: Science Applicable in Organizations," *Systems Research and Behavioral Science* 16, no. 1 (1999): 3–40.

Authors' Response

DesignX: For Complex Sociotechnical Problems, Design Is Not Limited to One Person, One Phase, or One Solution

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We thank the three commentators to our article – John Flach, Jeremy Myerson, and Peter Jones – for their thoughtful and constructive reviews. Their comments are precisely the sort of responses we had hoped for – useful extensions and critiques of our article. It is only through such detailed critiques that the field of design can make progress.

It is a simple statement that complex problems are not simple ones. It is more complex to go beyond that and keep the message simple. In our struggle to make sense of what is going on in the upcoming future of design, we are delighted to see the constructive reactions the commentators who are also struggling with these problems, addressing the changes and potential solutions from different perspectives, consolidated frameworks, and descriptions.

These commentaries exemplify the variety in framing and focus of our academic disciplines. They extend the range of cited works and areas of application. All of us are using design to link the social and the technical. Our different perspectives resonate nevertheless; and although they arise from different traditions, their combination is extremely rewarding.

John Flach eloquently brings together topics from engineering and psychology. He introduces Ashby's principle of requisite variety: namely, that the controls available to the operators must match the dimensions of complexity of the system. He also expands the literature of previous works in this area. We do disagree with his interpretation of the value of Ashby's Law. To us, this is a statement that we must reduce system complexity, thereby reducing its degrees of freedom. In our paper, we argued that human limitations require the simplification of systems – and Ashby's Law can be used in reverse to justify this. If people are unable to cope with the requisite variety, then reduce the requisite variety. Flach believes that this attempt – to reduce complexity – is wishful thinking, easier said than done. Which approach is correct? This is an empirical question, one that will be answered only through the efforts of designers to reduce system complexity and/or to match that complexity with the control structures available to human (or technological) operators.

Flach warns against blaming the human operator for the consequences of unrealistic demands imposed by defective design. He sharpens our discussion of the "human tendency to want simple answers" through his discussion of bounded rationality.

We agree with these points. This indicates that our paper was not clear in our discussion of human capability: We certainly did not intend that people be thought of as the weak link. The argument that we should recognize that all systems, natural or artificial, have bounded rationality is excellent. Our point was that, today, engineers design for the characteristics of the technology, ignoring human capabilities – except the ability to fill in where the technology is lacking. We argue that instead, things should be designed with the limits of human capability in mind. This point can be misunderstood to imply that people are the weak link; to us, however, it argues that people are the most important component in terms of design requirements.

Flach elaborates rightly that the limits of human cognition – both of the human operator and of the human designer – should be included in the design process, just like any of the other constraints presented by technical, or social, components.

We are grateful to Jeremy Myerson for providing the story of the redesign of the London emergency ambulance service that was also presented during the Shanghai workshop. Despite its clear success in winning design prizes, it has still not been implemented. This provides a powerful case study of the critical problems involved in implementation. As he put it, "Undeniably, the biggest barriers to implementation can be found in the social, political and economic frameworks: changes in the political and funding climate have blown our ambulance project off course…."

Furthermore, he emphasizes the limitations of the designers. Again, in his words, "The gap between the demands of today's complex systems and how most trained, hyper-focusing designers see the world is a chasm which all the categorizations of DesignX will struggle to bridge."

Peter Jones brought both a case study and a theoretical framework to the Shanghai workshop. In his comments, he further emphasizes a wary attitude about what a single design step can achieve. From his experience he brings both practical and formalized discussion of the social emphasis: perhaps instead of DesignX we need a "Socio-X" perspective. He also reminds us that these issues have a long history of study, providing a rich source of citations to the literature that we failed to provide – and in some cases were unaware of. Both Jones and Flach rightly criticize us for our ignorance.

The problems of working in these complex systems stem from the diversity of actors present in the arena; very few are aware of all the relevant work. We called for a different kind of design education, but Jones warns us that "Because it's unlikely that graduate design education will sufficiently touch on these perspectives and their case studies, we risk ignorance of this extraordinary developed knowledge – possibly dimly reinventing their models when faced with correlated insights, yet not benefit from appropriating the wisdom of 60-plus years of deep experience in these systemic perspectives."

All three commentators see that design and implementation are not only the remit of designers, but will involve a creative collaboration between a variety of actors and stakeholders. Design education will have to prepare future professionals for this dimension of collaboration. As Jones says, "we might ask: if 'we' across the design disciplines are not designing for complex sociotechnical systems, then who is? Are we ignoring these problems to some extent from conflict with aesthetic tastes, or because actually resolving these problems resists the rapid satisfaction of creative 'design thinking?' Or, are we shunning involvement with the depth of complexity, a lengthy commitment to a problem, and the inherent risks of bad design decisions? We might start finding in these critical problems the moral equivalent of infrastructure – we have to improve design for technological integration, because our lives and social ecologies depend on it."

What next? This combination of paper and commentary does not provide the answer to DesignX problems, but the discussion puts together a range of experiences, narratives, and framings from diverse design angles, identifying a number of issues and ingredients that have a shared perspective. The next steps will require addressing these issues. The result should be productive: better solutions and approaches for these large, complex, important problems of modern society, plus an enhanced, strengthened scope for design education.