

emerging **thought leaders**

A “Both/And” Kind of Dialogue

An interview between neuroscientist Scott Kelso and Lisa Kimball, President of Plexus

Neuroscientist Scott Kelso is a pioneer researcher in the field of coordination dynamics and a complexity scholar who has thought deeply about consciousness and the science of what makes us human. He holds the Glenwood and Martha Creech Eminent Scholar Chair at Florida Atlantic University, where he is also Professor of Complex Systems and Brain Sciences, Professor of Psychology, Biological Sciences and Biomedical Sciences. Kelso is also Visiting Professor of Computational Neuroscience in the Intelligent Systems Research Centre at the University of Ulster in Derry, N. Ireland. In a wide-ranging conversation, Kelso and Plexus Institute President Lisa Kimball explore agency, intention, leadership, paradox, the squiggle sense, the mysteries of the mind and the future of brain science.

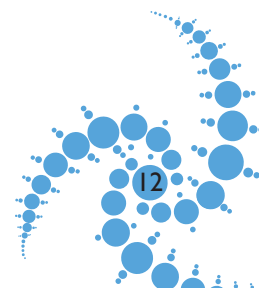
Complementary Pairs

Lisa: *One of the big topics in leadership development is moving toward “both/ and” thinking and the idea of being able to deal with ideas or options that are apparent opposites. In*

your view, is there a basis to say that we have a human capacity to deal with those kinds of things cognitively?

Scott: It might be a very rare human capacity! But it's more of a mindset problem I think. It was F. Scott Fitzgerald who said the secret of intelligence is the ability to keep two opposing ideas in your mind at the same time and still be able to function. No one said that was easy. That's maybe the big drawback. On the other hand, so many questions that we're confronted with in science and life seem to be of the “either/ or” type that it's useful to at least reflect that we are dealing with complex systems. There it may be a useful strategy to keep in mind what David Engstrom and I have called [‘the squiggle sense’](#), or the “both/ and” mindset.

So you hear about complexity science as the new science of emergence, and that says to many okay, now we're going to replace reductionism with emergentism—the parts don't really matter, it's the interaction between the parts that gives rise to emergent phenomena. The squiggle sense would say it does not make too much sense to replace reductionism with emergentism. Rather, let's



try to reconcile seeing things, not just from the bottom up, which is the reductionist style, but also from the top down too. The parts and the whole are a complementary pair—you can't have one without the other. They are co-implicative.

“...a major difficulty in perceiving and appreciating the complementary nature is its familiar invisibility. The tilde, or squiggle character helps us to not forget that complementary aspects are inextricably linked... though each retains its singular character.”

—From *The Complementary Nature*.

“reductionism~emergentism”

Lisa: *So that would be an example of a complementary pair....*

Scott: That would be a complementary pair in the context of scientific paradigms. Even sophisticated people will say we need to move toward emergent paradigms. And that may be true in the sense that you want to recognize complexity and that the whole is greater than or different from the sum of its parts. But at the same time you don't want to throw out the idea that you can decompose things into their parts, and that it's useful sometimes to do that. Synthesis~analysis is another complementary pair.

Lisa: *So why do you think we have a tendency to make these pairs? It seems like there's sort of a natural human attraction to them.*

Scott: Yes, it's very tied into the Western mind, and it goes back a long way at least to Descartes. We've thought of things in a dualistic way, and so we separated mind and matter. We've separated wholes and parts. We've separated individuals and collectives. If you say everything is a collective effect, and that's an emergent property of complex system, that's all very nice. Of course, you have to do some science on that, because many people talk about 'emergence' mystically and metaphorically. In complex systems, the parts can be really important and they often carry memory of the coupling with other parts and processes, and that can't be ignored. You can't just say these are collective effects and that's the only thing that matters. It's about understanding. It's not about pushing one notion over another.

Lisa: *Another tendency when we're talking about pairs is that we talk about balance, like when people talk about work/life balance. There's an assumption that somehow they're supposed to be equalized, but that doesn't seem to be underlying the squiggle sense. Somehow balance could mean we have the same amount of bottom up and top down, for example. So what does it mean to be thinking of them both at the same time?*

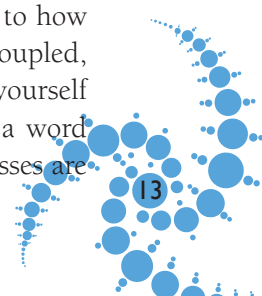
Scott: I think it allows you to step back and see, in the sense of understand, and we could talk about what we mean by understanding. Understanding for me means that from a scientific point of view, you choose a level of description and you try to identify what's relevant there, and what the relevant dynamics are—given very many aspects can be measured, but not all of them are relevant for a system to function. When you do, at least in some circumstances, it's very interesting that the dynamics are not fixed points and they're not chaotic. They're sort of in between—tendencies for attraction coexist with tendencies for repulsion. I call that metastability and I think it's telling us something really important. It means that apparently contrasting tendencies can coexist at the same time. In other words, metastability—beyond the world of states—is the origin of the 'both/and'. Notice metastability is just one regime of the dynamics. It's not that you replace “either/ or” with “both/ and,” because they're complementary. It's not that we're going to replace polarized thinking with living in ambiguity. No, the insight is to see that they are complementary too.

“either/or ~ both/and”

Lisa: *So wherever you are there's a complement, and at any level of the system, there's a complementarity?*

Scott: Yes, and I'm very excited right now, for example, with applying the principle of complementarity to how things are coupled. Everything in nature is coupled, from the molecular on up, and you can ask yourself what's the origin of the coupling? Coupling is a word used all over the place. Parts are coupled, processes are

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coupled, events are coupled—coupling is a key aspect of understanding communication and coordination. Coupling is a very powerful word in science and other fields. So what's the basis or origin of the coupling? I'm excited about the idea that complementarity might be the origin of coupling. Imagine the parts are uncoupled; that's one complementary aspect, right? What's the other complementary aspect? Well, the other complementary aspect is coupling itself, parts~coupling. So if you only have parts, and you ask what the origin of coupling is, and if you take as self-evident that parts~coupling are a complementary pair, the answer is complementarity. Taking this to its logical conclusion, it's not as if you have a God up there by himself or herself dictating to us mortals that truth and grace and eternity are absolutes. God has a complement too. Good always comes with evil, so complementarity is the basis of that as well. If you have one aspect, and you don't consider the other, you're going to be led into some very monotheistic, polarized view of the world. And of course, my God against your God is the source of strife and disharmony and violence.

Lisa: *So if you're trying to accomplish something, ask yourself what's the complementarity of whatever you are thinking about?*

Scott: If somebody is saying this is the way it is, this is how you lead, this is how you should do things, then I think it's useful to think what the complementary aspects are. And then you see it's not that there's this one way. It's about a mindset. And the key point here is that it's not replacing one mindset with another. Complementarity is not a new “-ism”.

Lisa: *That's a key insight because a lot of people seem to think that we don't want to do top down anymore, so we'll just do bottom up...*

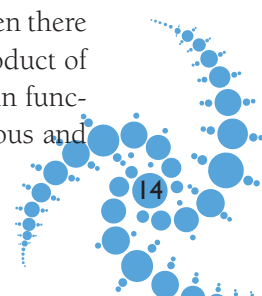
Scott: Some also speak about top-down in terms of downward causation. But this doesn't mean that bottom-up effects are not crucial as well. Or that vertical and horizontal integration are not both involved. I call it reciprocal causality. We seem to always want to replace one thing with another—one “ism” with another. That's not the picture I'm trying to convey at all. It's about a mindset that says there's always a complementary aspect, maybe several, and that allows you to open the thing up. The complementary mindset—the squiggle sense—generally leads to a broader awareness of things.

The Working Brain

Lisa: *Does the brain actually work differently when it considers something and its complement as opposed to only one thing?*

Scott: Recent work is showing that ‘at rest’ (as if your restless brain is ever at rest!) the brain's got a lot of ongoing spontaneous activity—what I call its self-organizing intrinsic dynamics—that we've not paid much attention to before. As the neuroradiologist Marc Raichle says, this is like ignoring the ‘dark matter’ equivalent of the brain. In the past, we've always tended to think of the brain as a reflexive entity, as an input-output kind of device. But in reality, the resting brain is consuming an awful lot of energy relative to the amount of energy that is used when a stimulus arrives. So the brain is not sitting there passively waiting for the world to excite it. Everybody kind of knows that, but it's interesting that the field has tended to ignore the brain's intrinsic, self-organizing activity. The assumption is that the action starts when there's an input and then the brain starts processing these inputs, making decisions in the context of previous memories, emotions and so on and eventually producing an output. But it turns out that even before a stimulus arrives, the brain is already in a very active state, and that its so-called ‘default mode’ or ‘resting state’ networks are already organized and actively ready to respond. It's these resting state networks, the self-organized intrinsic brain dynamics that's consuming most of the brain's energy for cognitive function. Typically, neuroimaging studies use some kind of experimental paradigm; let's say one that involves decision making. They then compare situations where you have to make decisions versus situations where you don't. The logic is that subtracting the brain images from the two situations should show which areas are active when you're making decisions. And then there are nice pictures that turn out to be mostly a product of the way you analyze the data. So once again brain function turns out to be a subtle blend of spontaneous and stimulus-dependent activity.

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We have to also recognize that living things are teleonomic, they are goal directed, and we don't really have much science for that. We've got the science of the living, and the science of the dead, and right now many people think that the science of the living is based on a dead molecule like DNA. In fact, the science of life is a lot more than that. How do you bring spontaneous self-organizing processes, emergent phenomena, into this picture? How do you bring in agency? It seems to me one has to see agency and spontaneity as complementary. Just like one has to see self-organization and natural selection as complementary aspects of evolution.

Lisa: *Makes me think of War and Peace, and the complementarity of free will and determinism. In one of the epilogues, Tolstoy raises the both/and question of how it can be possible for man to make choices within a framework where everything is thought to be determined by God. He suggests that it still matters what the individual chooses even if there is a larger cosmic "plan."*

Scott: Yes. It is very hard for us to see how free will and determinism can go together. Philosophers discuss this and it has seeped into neuroscience. We find it hard to reconcile these two notions, to see them as complementary aspects of one thing.

Lisa: *So is that like the particle/wave thing...you can't really see them both at once?*

Scott: I don't know. Wolfgang Pauli was called Einstein's conscience. He said the only acceptable point of view appears to be one that recognizes both sides of reality, the quantitative and the qualitative. The quantitative and the qualitative, the physical and the psychological, Pauli said need to be seen as compatible with each other. It would be most satisfactory if physics and psyche, matter and mind could be seen as complementary aspects of the same reality.

War and Peace, literature and science, with Niels Bohr, with Pauli, with Werner Heisenberg—these were some of the great minds of the twentieth century. What's new here, I think, is that you can actually demonstrate experimentally that complex systems like the brain can be in the either/or mode, they can be synchronized or desynchronized for example, but once you view the full complexity of the system, more often than not it's neither one nor the other. The system's sitting somewhere in between and the extremes, the either/or, are just sort of idealized states of affairs. Science likes to deal with

idealized states of affairs most of the time. We like to put things in neat categories. We have a tendency to impose order on the way we look at data. We like to say this is a pure thing, that's a pure thing and compare them. Hypothesis testing is like that.

Lisa: *Right, like whenever you're holding one thing constant while something else is happening. You can't really do that.*

Scott: That's a classic one, the dependent and the independent variable. But what can be an independent variable at one level can be a dependent variable at another—same with order parameters and control parameters, quantitative and qualitative. So it's more obvious in a way that these are not separate but related things. They both contribute to how we try to understand phenomena. People say we study the things too much. We're studying neurons. We're studying genes. We're studying cells. Then they say what we really need to do is understand the relations or the interactions between things. Again, that's fine as far as it goes, but you need to have both. You need to have both the dancers and the dance.

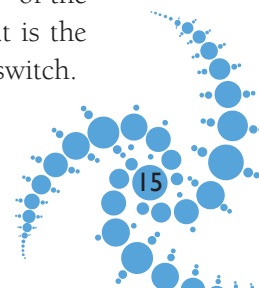
"multistability~metastability"

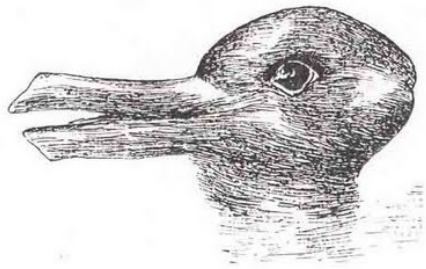
"In coordination dynamics, as symmetry is broken and couplings are altered, multistability, in which several functional states may coexist—gives way to metastability, in which only tendencies coexist."

—From *The Complementary Nature*

Scott: Laws and mechanisms are another complementary pair. Biologists love the word mechanism and physicist tend to look for laws. I just wrote a paper for the Philosophical Transactions of the Royal Society in London. I was invited to address the issue of multistability. Multistability means that you can have several solutions for the same set of inputs. Perception, for example, can be multistable. Like if you look at a Necker cube—or the duck-rabbit illusion, where the perceptual input is the same but your interpretation can change, it can switch.

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Once you've seen both the rabbit and the duck, you can't "unsee" them.

Lisa: It's interesting with those kinds of things that once you're seen both, you can't not see them both.

Scott: Yes, that's a situation where you get several interpretations of the same physical input, and then, as you say, once you have a particular interpretation it can bias what you see. So it's that kind of a circularly causal kind of system. Multistability is seen at every level. It's seen in molecules. It's seen in societies. So it's a very universal property of matter and its organization-- yet the mechanisms by which it's realized are practically infinite.

If you're after understanding universal aspects like multistability, one way is to study a particular realization and that's fine, but it means you end up with a single mechanistic account of the phenomenon. Multistability in a system usually means it can exist in multiple states. Metastability means you only have tendencies or propensities, or predispositions. Multistability itself is a very general and lawful aspect of complex systems and it turns out that the more general the situation is, the more you've just got tendencies, not really states at all. We have coexisting propensities, predispositions and tendencies, but they are not to be equated with states of affairs.

And they're not really stable because to be stable means that you're in some kind of state for a long time, and things are not really like that. Yet they're not chaotic either. They're not unstable. They're not repelling states. So that's a key aspect of metastability. It's a kind of dwell-escape dynamic. Slowly and surely metastability is gaining leverage in our explanations of how complex systems behave. But it'll take time.

Lisa: So how are you studying multistability?

Scott: There's a huge literature in brain science. You see what it allows you to do, if you have the same physical input, and the brain, or the brain-mind, is switching

from one interpretation to the other, that's sort of an in-road into consciousness, or conscious awareness.

Because usually, you might think there's a mapping of the input to the perception, of the stimulus to the perception and that it's mono-stable; that there's some kind of direct mapping from the input into your awareness. Well, here's a situation where actually, your awareness switches spontaneously, and so you go after the neural correlates of that. The literature's full of it.

You can show this effect in the visual system, the auditory system, the tactile system, the motor system, in learning, and there are neural correlates. In other fields, such as molecular biology and chemistry, multistability is well known. Molecules can exist in multiple states. People have talked about this being crucial for selection...that selection would operate on a system that can be in multiple states, depending on the environmental circumstances. So it runs through a lot of scientific levels.

Lisa: How can we be more open to multiple interpretations?

Scott: Well, the primary example of multistability is the case of bi-stability. You have two alternatives for the same input. So the very objects of people's concerns already exhibit bistability. Neurons are bi-stable. They can be on or off and they have threshold properties that allow them to exist in several modes for the same input. People are finding these things out all the time. This is the nonlinear dynamics of the nervous system.

The complementary nature is about a mindset. It's about a way of looking at things and yin-yang is just an ancient example. Yin-yang is just a manifestation of a deeper principle called complementarity which arises from metastable dynamics.

It's how you look at the data. Scientists like to look at data in a very orderly way. And they like to see order in their data. They love order. Then they say the rest of it is noise. But signal and noise are a complementary pair. Metastability says you're neither purely integrated nor

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purely segregated, you're neither completely cooperative nor competitive.

You're neither individual nor collective, where those words are used as pure categorical states of affairs. I actually could live in a world where people were neither manic nor depressed. I could live in a world where there's neither peace nor war. In a way, I think it would be a much better place.

Lisa: *What's the complement to yin-yang?*

Scott: Yin-yang, the ability to see both sides, is the complement of polarization, the either/or. Yin-yang is reconciliation. And polarization~reconciliation is itself a complementary pair.

Lisa: *About complexity—there's sort of a fractal aspect to it because no matter where you are, you think you're sort of at a set point. But then it turns out there's a perspective that's bigger than that, that has the complement in it.*

Scott: Yes. What does fractality mean here? Does it really mean that the parts and the processes are self-similar all the way down, that there are multiple space and time scales involved?

Fractals are a way of seeing commonalities across scales or levels of description. Well, if there are similarities across scaling levels, then complementarity says there are differences as well.

Lisa: *I have an image of a magnet. It pulls its complement and yet it can also push its opposite away. That dynamic seems to create energy.*

Scott: Yes, that's interesting. If you have one complementary aspect, it implies the other. If you say the world is just about parts, and you don't think about the whole, then you can't understand the world. Dichotomy is very useful sometimes, but it can mislead too.

Acting and Agency

Lisa: *So let's get back to agency. So now, I'm an actor in this system, and I'm aware of the complementarities. And I need to make choices about something to do, and for a nanosecond I have to act with one selected perception rather than another. But as soon as I've done that, I've set up a whole other portfolio of choices that emerge from the first choice, and*

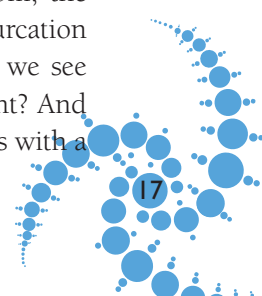
there are a bunch of new complementarities that are based from the new place I am, wherever that is.

Scott: You're talking about decision making. Yes, one should go into that a little bit because what I have in mind here is that you have alternatives and you can adopt one or the other. That's quite a legitimate form of thought. So bi-stability here would be the basis of the either/or. I can be in one state or the other. I have at least two states, and I can switch between them, and these switchings are sometimes called phase transitions or bifurcations. But then if I just open up the system a little bit more, 'break its symmetry' as we would say, I have a situation where former stable states become tendencies. Unlike states, tendencies have no stability. But both tendencies are now available and they co-exist—you are neither in one nor the other, and the repertoire of possibilities depends on many factors. If you're standing on a precipice, you're not thinking about the complementary nature. You're thinking about how to survive. Survival is one aspect, but not the only aspect. So it's only after you survive that you could maybe reflect on the conditions that got you there.

Lisa: *So what questions, or avenues are you most excited about exploring in your own work now?*

Scott: My passion is the science of coordination, coordination dynamics, which is how I came to all of this anyway. I think coordination is at the heart of understanding living things because you simply can't ignore functional aspects. It's not just physically inspired notions of self-organization that matter for coordination, you have to bring in teleonomy. You have the directedness of living things, and that's one area that I'm thinking about a lot. So I'm thinking about where agency comes from, the origins of agency. Was that some kind of a bifurcation that arose out of spontaneous activity, or must we see agency and spontaneity in a complementary light? And one way I'm investigating that in the laboratory is with a

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virtual partner interaction paradigm, which is very cool. It may open up some nice avenues.

Lisa: *Give me the short version of how that works.*

Scott: You have a human interact with a computer model of a human, albeit in a very restricted sense. You are now coordinating your hand movements with an avatar, which is driven by the equations of motion that Hermann Haken and I developed to describe your own hand movements. The key to coordination is bidirectional or reciprocal coupling. You modify the behavior of the avatar and it modifies your behavior. This issue of bidirectional coupling turns out to be pretty crucial for everything because nothing happens in nature without coupling, and that's where I think the complementarity story comes in big time, because I think that complementarity is at the basis of coupling. So you now have a human interacting with an avatar. They're coordinating and because you have control of what the avatar does, you can set it up to have an entirely opposite intention to the human. You can put the two in conflict. For example, the human is asked to coordinate in phase with the avatar, but the avatar's parameters have been set so that the avatar wants anti-phase. So the avatar is in conflict with the human, and they have to somehow resolve it in real time. So what we are looking at is the real time dynamics of this conflict~ cooperation situation between the human and avatar. In a coordination situation, who is the leader and who is the follower? The virtual partner interaction paradigm opens that up to experimental and theoretical study.

We've been doing research on leader~follower dynamics. You do a lot of work on leadership, Lisa. Well, a complementary aspect of that is followership, and that dynamic has to be explored. The leader~follower dynamic is very interesting and can be modulated by a whole bunch of factors. The interesting thing in this conflict circumstance that I've described is that at a certain point in time and for certain conditions about which I can't tell you specifically at the moment, the human has the phenomenological experience that the machine is messing with them. In other words, the human ascribes agency to the machine.

This opens up the possibility of obtaining objective descriptions of so-called subjective phenomenological experience, an issue that in my view has been swept under the carpet in many fields and science in general.

Psychiatry, for example, looks for objective descriptors of mental experience all the time now and in doing so sometimes fails to see the intimacy between the subjective and the objective. We do not have, outside of literature, a very good language for subjective first-person experience, and moreover, we do not understand what the objective correlates of subjective experience are. It's a big gap.

So that's one area. The complementary nature sees the object~relations issue, the subjective~ objective distinction as complementary and is interested in understanding what that complementarity is all about. So I think, for example, that when a human is trying to coordinate with an avatar, there's a discrepancy between what the human's doing and what the avatar is doing, and that this discrepancy, which can be observed and quantified, evokes the human's reaction. So there's a certain discrepancy between what's expected and what actually occurs, and this leads to the triggering of phenomenological experience. That looks to me to be an interesting line to think about.

Other areas of research have to do with the individual and the collective and again, the focus is more and more on how brains interact. These questions are very much tied to the complementary pairs of individual~collective, cooperation~competition, integration~segregation and so on, all of which pertain to how things—from cells to societies—are coordinated or organized.

I would love to get your notions on that and how this kind of mindset, which I think you have, might be useful. I'd be very interested to hear your thoughts on how this kind of mindset can be effectively transmitted to others.

Lisa: *For sure we've discovered that people need to experience this way of thinking rather than reading or being told about it. One of the approaches we've used is introducing the notion of "wicked questions" as a way of reframing challenges that appear to be dichotomous. For example, how can we maintain centralized quality standards while allowing room for local innovation? That's a more generative question that "How can we make everyone implement this program 'right'?" Giving leaders an opportunity to practice and reflect on this different way of thinking can flip the switch so it's not just an exercise at a meeting but rather how people think all the time. That's the next mountain to climb! ■*

