# Psi , Influence and Link Theory

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## 1) Time and causality

Trying to create a science of parapsychology with our present primitive understanding of causality is like trying to do long-distance navigation with a map of the flat Earth; in each case one encounters the problem of *non-locality*. To ask what "causes" clairvoyance or telepathy or precognition is like asking how people can instantly sail from the East edge of the Earth to the West edge of the Earth. The problem isn't just wrong assumptions or wrong theories; it's worse than that. Pauli once remarked of a colleague's presentation: "That's not right, that's not even wrong!" I'm afraid his remark fits most of what science has to say about psi. We are like a tribe so primitive that it has no word for roundness. For such a tribe, the question of whether the Earth is flat or round cannot even be asked. Is the Earth flat or is it <blank>?

Is psi causal or is it <blank>? That's a non-question for the scientific community today. Link theory aims to fill in the <blank>.

Causality is closely related to the arrow of time. There is a parallel between our problem with time's arrow and the ancients' problem with up and down. For the pre-scientific mind, up and down are intrinsic to space itself, which is why the round Earth had such a hard time gaining credence, despite the overwhelming evidence in its favor. The practical needs of long distance navigation finally triumphed over instinctive prejudice, but up-and-down still remained a mystery until Newton realized that the arrow here is not a *property* of space at all, but rather a *relationship* between massive bodies. There is an analogous solution to the problem of time's arrow, which is that it is really not a property of time (or of space-time) at all, but rather a relationship between "bodies" of *information*. Link theory gives the conceptual framework in which this relational solution can be stated mathematically. As with Newton's gravity, the strong directional arrow of time characterizes the situation of small informational "bodies" in the neighborhood of a much larger informational "body". Such "bodies" are actually *events*. When these events are more nearly equal in size, the situation becomes more complex, and the simple arrow of time gives way to a multi-event relationship, just as the arrow of up and down among the satellites of Jupiter gives way to a multi-body relationship.

Though the breakdown of an absolute distinction between past and future is baffling to common sense, it is quite harmonious with the larger picture of the universe that has

emerged from physics. After all, Newtonian dynamics is completely reversible in time, as is quantum mechanics, and Einstein's general theory of relativity has led astronomers to the discovery of domains of space-time (black holes) where time-lines are cyclic. A supposed earmark of the absolute difference between past and future is the openness of the future, in contrast to the closed-ness of the past where everything is determined once-and-for-all. But how could there be an open future in a cyclic time? A more "scientific" earmark of time's arrow is the steady increase of entropy. But how could entropy increase steadily around a closed loop?

As with up-and-down, the cognitive dissonance here between common sense and reason has to do with habits of thought that are probably hard-wired into our genes, and are thus very difficult to overcome. The most wonderful new discoveries about black holes, superstrings, space knots, complexity theory or whatnot, will not help us one iota with psi until we have overcome this cognitive dissonance by clarifying our fundamental ideas..

Like Newton's clarification of up and down, the link-theoretic clarification of past and future is only a first step. In both cases, the second step is an even greater insult to "animal faith" than the first. The second step for up and down is Einstein's amazing insight that these really belong to space after all, albeit to a new kind of crooked space than also includes time. I believe that the second step for psi will be the assimilation by link theory of Von Neumann's deep discovery that Boolean AND and OR are relative in the quantum domain. But that's another story.

## 2) The arrow of influence

So how do we use reason to do an end run around our hard-wired habits?

But first: Why should we want to?

Instincts are formed over the eons as automatic responses that make for efficient functioning in relatively stable environments. When a creature moves to a very new environment, some of these automatic responses may be completely wrong, as when a rabbit freezes in response to oncoming headlights. Thanks to science and technology, the whole human race has, so-to-speak, wandered onto a superhighway, and it looks as if it will quickly become road-kill unless it starts using its reason in heroically new ways.

Fortunately, unlike rabbits, human beings *can* reason, even though it pains them to do so. That is to say, humans can sometimes arrive at decisions and judgements by not only responding to impulses and images, but also by manipulating *symbols* in a way that reveals otherwise inconceivable options. Ideally the two ways of functioning go together, and the most important accomplishments of reason transform our imagery as much as they transform our beliefs. For this reason, I will start out here with some traditional images of time-direction and causality, and then show how these can be "morphed" by symbolic reasoning into something better suited to our present needs.

Though philosophers like to talk about causes and effects, in our everyday experience causes and effects are but isolated incidents in a pervasive field of *influences*. Let's visualize an influence as an *arrow*. Sometimes this arrow goes from one thing to another, sometimes from one event to another. The kind of arrows that go from one event to another are more basic, since the persisting influence of a thing A on a thing B can always be regarded as a series of influences by events involving A on events involving B.

Now big events consist of smaller events, and understanding how things "work" usually means taking apart fuzzy arrows among big events into sharper arrows among smaller events. Let's visualize these smaller events as *nodes* in a graph whose lines are the arrows of influence. A node, then, represents a small region of space-time. How small depends on the context; for the particle physicist it could be an electron for a nanosecond, while for the astronomer it could be a galaxy for a million years.

What's makes such a diagram useful is that it abstracts the *connectivity* of influence from the details of space, time and matter. Concerning such connectivity, there would seem to be one undeniable law: *arrow heads come after than their tails*. From this law it follows that there cannot be cycles of arrows, and this so far is the sole restriction on our diagrams.

What do we mean by influence? Influence is so much a part of everyday experience that it hardly calls for a definition. Indeed, along with other basic ideas like 'here', 'now', 'this', 'I, 'we' etc., that of influence seems to be an essential working part of the very machinery of thought. If this is true, there is no way to define it without using it; the best we can do is to understand how it relates to other concepts.

Influence is the *exercise of power*. Influence means *shaping how things happen*. To influence a situation means to *alter the range of possibilities* for events in that situation. Such an alteration can be in what is *required*, or in what is *allowed*, or in what is *prohibited*, or in what is *probable*, or in all of the above.

These alternative words for influence are all tied to the human experience of exercising power, of being in control. What, then, does it mean for a mere physical object to influence another mere physical object? For one thing, it can mean that object A is our helper, our tool, our *means*, for doing something to B that we want done. When we see that A influences B, for instance that rain influences the grass to grow, we are usually also at least peripherally aware that we ourselves could *in principle* use A as a means for exerting our own influence on B, for instance, we could water the lawn. Even when we study the influences at work in the most remote and esoteric domains of nature, somewhere in the back of our minds there always lurks the question "How might we put all this to work for *us*?" This is not surprising, since our genes are more concerned with our practical well-being than with our abstract understanding of the universe.

The arrow of influence was described above as going from one event to another. This is not quite accurate. Consider the following conversation:

"I played tennis this morning."

"Why are you telling me this? You always play tennis in the morning."

As versus this one:

"I played tennis this morning:

"Congratulations! I see I'm having a good influence."

Comparing the two, we see that influence, properly speaking, does not act on the event of playing tennis itself but on the situation in which that event is a possibility. You can't influence events that always happen no matter what, just as you can't influence events that have already happened. For an arrow from A to be called an influence on B, the situation cannot be one that presents B as a foregone conclusion; rather, it must present B as one of several alternatives. Either I drag myself out of bed and play tennis, or I sleep for another hour. Even if I always succeed in dragging myself out of bed, the option of sleep must always be there if the good influence is to continue to qualify as such. Thus the arrow of influence does not, strictly speaking, connect an actual event A to an actual event B, but a range of possible events A to a range of possible events B. Keeping this in mind, we can still use the language of events influencing events, but with the understanding these are *variable* events.

As mentioned, there's one thing our genes would seem to be very clear about: influence always flows from past to future. We set our goals for tomorrow, not for yesterday. Arrow heads are always *later* than their tails. This, of course, is why we have so much trouble with the physicists' time loops, and of course, with precognition.

Suppose there is an arrow from event A to event B and another arrow from event B to event C. When A happens, this limits the possibilities for B, and the fact that B must be confined to this smaller range in turn limits the possibilities for C.

Physics says there are loops in time. This, according to what we have assumed, would allow for a third *backward* arrow from C to A. If an arrow is defined as something that narrows the range of what is possible, then this backwards arrow must limit what is possible in the situation of A. But A has already happened! No further limitation on the situation of A can be imagined. Instinct simply goes tilt. Forget about it, replay the game, erase the tape, start over.

Scientists have the same genes as the rest of us, so what makes them able to talk about time loops in black holes? They do it simply by changing the subject. The "time" of Einstein's space-time is not the time we actually experience, the time in which tomorrow's

events don't happen until tomorrow . The physicist's circular time is just a dimension of an imagined four-dimensional curved space. Such so-called space-time can be studied as if it were something timeless and completed. The "events" in space-time do not *happen*, they are simply *given*, like the words in a history book. In curved space-time, a circular "time-line" is no more mysterious than a circle around a cylinder in ordinary space.

All this works fine for distant galaxies, but it won't do at all when we get closer to home, as when we try to think about time loops that arise from our own precognitions. Confronted with such oddities, scientists go tilt along with everybody else. But *science isn't allowed to go tilt* – ergo the alleged phenomena are "scientifically" impossible!

As we'll now see, this freak-out by science is quite unnecessary. There is in fact a relatively easy way to avoid going tilt over the A, B, C loop, even for precognition. It does require us to give up certain of our old habits of thought, but what it puts in their place holds no mysteries, and is based on quite ordinary mathematics.

## 3) Link theory

The family of words like *cause* and *influence* also includes the word *function*. A gadget is *functioning* properly when its buttons and dials *cause* the appropriate responses. To say that A *influences* B means that something about B is a *function* of something about A. Though the concept of function in pure mathematics has been attenuated into that of a bare mapping, it still retains its causal connotations in empirical science. Especially in the more worldly sciences, one tries to make sense of a complex whole by describing it as a *functional systems* whose parts are *simple functions functionally composed*.

Link theory replaces functional parts by *relational parts*, and functional composition by *relational composition*.

We speak of a *determining* influence when the state of B is a function of the state of A. It's more common today for science to work with *probabilistic* influences, where the state of A determines not the actual state of B but the probabilities for the possible states of B. We can still fit such analysis into the functional mold by defining a probabilistic influence as a function that maps the set of all *probability distributions* on a state variable of A into the set of all *probability distributions* on a state variable of B. This of course reduces to the deterministic case when the probabilities involved are just 0 or 1.

It is useful to represent a probabilistic influence by a so-called *transition matrix* whose column index is a state variable of A, whose row index is a state variable of B, and whose ij'th entry is the probability of i given j. Multiplying such matrices corresponds to the chaining of influences, which gives rise to the notion of a *Markov chain*. This is a more general concept than it might at first seem; it covers computers, with or without random inputs, and any

process that can be realistically modeled by computers. It is hardly an exaggeration to say that the goal of most scientific enquiries is to find explanations that have the form of Markov chains. (A word of caution: The terms "Markov chain" and "Markov process" have been used in a variety of inconsistent ways, and our informal account here makes no attempt to sort these out; for a more rigorous discussion see [1] )

The "black boxes" that are chained in a Markov chain have only a single input and a single output representing the complete state variable of the system as it changes with time. We usually try to analyzes functional systems into smaller functional units; for instance, we analyze a computer into its logic gates. Such units will often have more than one input, but otherwise they are described in the same way as Markov boxes, i.e., by the rule that gives their output probabilities as a function of their inputs. Connecting outputs to inputs generalizes Markov chaining, but the succession of total states in such a generalized system is still a Markov chain.

Link theory covers the same ground, but does so in a mathematical language that enlarges this ground. Link theory is a so-called *covering theory* for the theory of functional systems (it's also a covering theory for quantum systems, but that's another story.) Going to the link-theoretic description of a functional system involves two steps: 1) Replace functions by *functional relations*. 2) Define probabilities by *case counts* for *hidden inputs*.

By a *functional relation* is meant a statement like y = f(x). By *linking* two statements is meant *identifying* a variable in one statement with a variable in the other. We link y=f(x) to z=g(w) when we replace w with y, giving us the two statements y=f(x) and z=g(y). Notice that, after they are linked, these two statements together tell us that z = g(f(x)). That is, the two statements that results from linking the argument variable of a functional relation with the resultant variable of an independent functional relation, when they are taken together, imply the functional relation of the composed functions. Here is our first rule:

Rule 1) Replace descriptions in the language of functional composition by equivalent descriptions in the language of linked relations.

We saw that the language of influence goes tilt when it tries to deal with cycles of influence. This fragility carries over to the more formal language of functions. What would it mean to have a cycle of functional composition? A recursion, perhaps? No – a recursion is a cycle of *types* of functions, not a cycle of *instances* of such types. Such fragility is not shared by the language of relations, though. There is nothing to stop us from linking both variables of y = f(x) with both variables of z = g(y), which would simply give us a pair of simultaneous equations.

Already we have taken an important step in dealing with the "paradoxes" of precognition. We see that whatever else we must do, we must substitute the language of relations for the language of functions.

Since probabilistic systems like Markov chains can be treated as functional systems whose variables range over probability distributions, we can apply step 1 to them too. However, the language of functional relations provides a way to deal with probabilities that avoids the need to reify and operate on distributions as a whole. This brings us to step 2. Instead of introducing transition probabilities as additional structure, as we did above with Markov chains, we shall derive them from the structure of functional relations themselves. Here is a brief account of how this works:

An *input* to a system is by definition a variable that contains no information until it is linked to something outside the system. Let's then divide inputs into two classes: those we want to control or keep track of, and those we want to ignore. An input we want to ignore should not be treated as containing any information; after all, "unknown" information is no information. Under Shannon's definition of information, this means that we should treat the values of ignored inputs are *equiprobable*. Also, we should not assume that there is any correlation among ignored inputs, which implies that their joint values are equiprobable. Such equiprobable joint values will be called the *hidden cases* of the system.

Rule 2). Given a deterministic influence with hidden inputs, treat it as a probabilistic influence whose transition probabilities are given by counting hidden cases.

Here's a simple example. Consider an AND gate with inputs x, y and output z. Hide input y. The result, by Rule 2, is a probabilistic influence of x on z having the 2x2 transition matrix 0, ½, 1, ½. It's easy to see how we can create any (finite) transition matrix whose probabilities are rational numbers by applying Rule 2 to a suitable deterministic influence. In itself, our second step is not at all radical, and is easily incorporated into computer science; for instance, a computer programmer doing a real-time simulation of a Markov process might well use Rule 2 to simulate random transitions, with the Rnd function assigning equiprobable random values to hidden inputs of a programmed function.

Step 2 becomes radical, however, when we combine it with step 1. When we chain probabilistic influences, we multiply their transition matrices, which is how we compose linear functions on a vector space whose points represent probability distributions. Linking does something entirely different. The functional relation of our AND gate is the statement (z = x AND y). Let's use the prefix (Hy) to mean that we are hiding y. Thus the statement (Hy) (z = x AND y) defines a *joint probability distribution* p(x, z) on the variables x and z, where the probability of a given pair of values of x and z is the number of hidden cases for that pair divided by the total number of hidden cases. When we link two copies of that relation we get a statement of the form (Hy,y')S(x,x',z) whose pair of hidden binary variables produce four hidden cases. Hiding the link variable x' gives a statement in two variables whose transition matrix is the square of the AND gate matrix described above, as the reader can easily verify. Notice that we were able to arrive at this result without thinking at all about functions on probability distributions.

Link theory and standard transition theory, despite their very different logical structures, completely agree for Markov chains. In so far as Markov chains capture the essential structure of influence, link theory does too. But where link theory comes into its own is in dealing with influence diagrams that contain *cycles*. We saw above how this works for deterministic influences, but it works just as well for probabilistic influences. *Any* influence diagram, whatever the connectivity of its arrows, has a formalization in link theory that determines probability distributions on every variable and combination of variables.

An arrow diagram of component functional relations is simply a set of simultaneous equations. When we hide certain variables, the number of solutions of the equation set becomes a function of the unhidden variables; these numbers are the hidden case counts. Dividing these counts by the total number of cases gives us our probabilities.

Scientists who disbelieve in psi usually claim that the alleged phenomena would violate well-established laws of nature, chief among which is that "causes can't go backward in time." This is hotly denied by psi partisans, of course. What both sides usually fail to recognize is that neither has the foggiest idea of what they mean by causes going backward in time. I hope the above discussion has made clear that there actually is a mathematical framework that *generalizes* the scientific conception of causality in a way that removes its necessary unidirectonality.

Does this mean that causes can go backward in time?

Does Newton's discovery of gravity means that things can fall up?

## 4) The round Earth

The Earth became round in about 600 BC and remained round until about 400 AD, when it was flattened again by a strange alliance between religious fundamentalism and advanced technology. This was still before the Dark Ages, and the savants who flattened the Earth were well schooled in the works of Aristotle, Ptolemy and Aristarchus. But they were also aware of the amazing inventions of Heron of Alexandria, who not only built steam-powered toys but put on a completely mechanized puppet show, and this new technology of complex machinery provided the material for their arguments. The "new astronomy" was spelled out in a three-volume treatise by a certain Kosmos of Alexandria [2], a work containing a detailed description of the universe as a giant planetarium in the shape of Noah's Arc, with the flat Earth as its floor. An elaborate system of stage machinery, designed by God of course, pulled the heavenly bodies around in precisely those orbits described by Ptolemy et. al., thus creating the observed celestial show. This new astronomy was apparently well-received by the intellectuals of the time.

Why, after a thousand years, did the Earth become flat again? Certainly one reason was nostalgia for simpler times, but another is that the arrow of up and down was still regarded

as a property of space itself. This really does make the idea of a round Earth confusing. Even Lucretious (circa 50 BC) , in his account of the strikingly modern relativistic cosmology of Epicurus, is silent about the Earth's shape. This is not surprising, since the Epicurean cosmology presents things as everywhere falling. 400 AD was a time of rising social chaos and cultural confusion, so it is understandable that people wanted firm and clear ideas to hang onto, and confusions about up and down were hardly welcome.

Today most of us still think of the arrow of time as an absolute property of time itself, despite the absence of that arrow in the laws of mechanics. The situation is undoubtedly confusing. We should not be too hasty to laugh at the confused ancients, considering our own confusions about past and future, and judging by our tendency to make computer models of everything including ourselves, the ghost of Kosmos may still be with us.

In Section 1 it was remarked that link theory provides an alternative *Newtonian* theory of past and future. We are now in a position to pursue this further.

The best-known and most clear-cut physical manifestation of time's arrow is the irreversible increase of entropy mandated by the second law of thermodynamics. Today we realize that entropy is closely linked to information, and if we take entropy in a broad enough sense, the two are actually the same quantity with opposite signs. With this in mind, the idea that time's arrow is a kind of "gravity" in the vicinity of massive bodies of information no longer seems so far fetched.

As mentioned, a "body" of information in the present sense is not an object that persists through time, but is more in the nature of an event. Our first pass at a theory of "informational gravity" will maintain a clear distinction between *informational space* and *informational matter*; in this we are following Newton rather than Einstein. Let's start out by thinking of this informational space as a cellular automaton in which the cells have inputs. "Matter", then, will consist of *values assigned* to these inputs, which gives it the dimension of information. Let's ignore the unassigned variables, in the sense of "ignore" discussed in Section 2, thereby making their transition boxes probabilistic. If no variables are assigned, we'll regard the history of our automaton as *empty space-time*. The assignments in a certain region of this space time will constitute a "body." For most automata, some part of this body of assigned information will persist in empty space after the assignments, gradually fading away with the passage of time; this fading away is the second law at work.

Our automaton model is of course completely unidirectional in time. No information from the body will ever be found *before* the assignments of values to inputs, and time-cycles are inconceivable. However, the situation is very different if we use link theory to construct *relational* rather than *functional* cells for our empty space. Such a relational array can be completely symmetrical in past and future, and indeed, homogeneous in all directions. Link theory, as we saw, replaces assignment by *linking*; we "assign" the value k to a variable x by linking x to y in the functional relation y=k. Matter, then, consists of a break in the symmetry of the array produced by linking definite values into the variables of a region. The

resulting "body" will "radiate" its information in all directions. The second law takes the form of an attenuation law with distance; the information from a body on an enclosing surface of empty space falls off with the distance between that surface and the radiating body.

If there is only one radiating body, the arrow of time is simply the arrow away from that body, and it is unidirectional. With several bodies, however, the situation can get much more complicated, and one often needs the mathematics of link theory to get even an intuitive idea of the what's going on. There is, however, a kind of *local* manifestation of the radiated information from several bodies that is quite analogous to the gravitational field, in that it is characterized by a simple structure which is independent of the details of the system of radiating bodies. This structure is called the *density matrix*, and it occurs at every link, being simply the hidden case-count matrix that results from *breaking* that link. Ordinary one-way time has a clear and simple local signature, which is that one of the broken ends contains no information. There is a continuum of cases between all the information being in x to all the information being in y, which takes us smoothly from forward to backward time. The case halfway between, where x and y have the *same* information, is of particular interest, since it turns out to completely characterize the basic laws of quantum mechanics, but that's a another story [1]

What's important for our present topic is the mathematical fact that we can, using the density matrix, precisely describe the local manifestations of "backwards time", just as we can describe the rate at which bodies fall without knowing the source or sources of the gravitational field. This local analysis reveals that entropy, or more exactly, change of entropy, is the sum of two components, one oriented backward, the other forward in time. We are apparently living in a strongly polarized past-future field, where the backward component is too weak to have measurable effects on thermodynamic entropy. Even so, it could play a very significant role in steering complex informational processes via triggering events, and it makes good sense to look for the signature of such steering in the data of psi.

Our cellular model of space-time raises two questions: What, in relational terms, is a cell? and where does the local information come from? I believe that both questions are spurious. To get rid of them, though, calls for a Einsteinian correction of our Newtonian thinking. The notion of space-time as a regular array of cells must give way to the notion of space-time as a homogeneous manifestation of relational disorder which becomes smooth when it reaches a certain scale. Matter, then, is not anything added to space-time, but the manifestation of more orderly patterns of linking that "warp" the smooth large-number symmetry of empty space-time. The quantum nature of this space-time is contained in the very structure of linking itself, as mentioned above.

The mathematics required to actually construct such a radical theory of the physical world is still in a primitive stage and will take a lot of hard work. Perhaps the needs of parapsychology will motivate us to do some of it. Since the study of psi began as a search for

the immaterial dimensions of the world, it would be a curious twist of fate if the fruits of that search turned out to be a unification of our two major theories of matter.

References:


1. *Process, System, Causality and Quantum Mechanics* by Tom Etter and H. Pierre Noyes SLAC-PUB-7890
2. *Theories of the Universe* ed Milton Munitz, The Free Press, New York, pp. 116-125