Changing the Subject:
Redei on Causal Dependence and Screening Off
in Relativistic Quantum Field Theory

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Abstract

In a recent pair of articles (Redei 1996, 1997), Miklos Redei has taken enormous strides toward characterizing the conditions under which relativistic quantum field theory is a safe setting for the deployment of causal talk. Here, we challenge the adequacy of the accounts of causal dependence and screening off on which rests the relevance of Redei's theorems to the question of causal good behavior in the theory.

1. Introduction Non-relativistic quantum mechanics posits correlations, even perfect ones, between spatially separated events. Suggesting spooky action at a distance, these correlations gave Einstein the creeps. They haunt others too: a bountiful literature addresses the question of whether distant Bell-type correlations reveal the activity of superluminal causes at the quantum level. Part of what nourishes this literature is folklore's insistence that the Special Theory of Relativity (STR) prohibits faster-than-light causal influences. An interpreted quantum theory committed to such influences would be incompatible with STR thus understood. But perhaps the worst sort of incompatibility would be one which arrests physics, by rendering physicists incapable of building new theories incorporating both quantum and relativistic elements. Fortunately, in relativistic quantum field theories (RQFTs), we have what amounts to a *prima* *facie* constructive proof that the situation is not so dire. But while soothing incompatibility worries raised by the spectre of superluminal causation, RQFTs don't thereby lay that spectre to rest. For RQFTs sustain states—notably the Minkowski vacuum state—which institute problematic correlations between observables pertaining to spacelike separated regions. These correlations are *thoroughgoing*: for any two spacelike separated regions, the Minkowski vacuum correlates any observable from one with some observable from the other (Redhead 1995). And they're *generic*: any RQFT admitting one state instituting such correlations admits a dense set of such states (cf. Clifton *et alia*, 1997). So, are the vacuum correlations of RQFT evidence of superluminal causation?

In the RQFT setting, the issue is less urgent than in the non-relativistic folkloric setting, where a positive answer rushed the STR to judgement. Here a positive answer simply indicates that causes in RQFT aren't behaving *as causes ought*. The Lorentz invariance of RQFT doesn't prohibit the superluminal causation intimated by distant correlations but exacts for it at least this price: the availability of reference frames in which superluminal causes come *after* their effects, in gross defiance of our expectations about the invariance of causal priority. But why should it matter whether causes in RQFT behave as causes ought? One sort of answer to this question starts with the idea (a venerable one, and not crazy) that we acquire scientific understanding of a domain by figuring out how causes operate there. Reichenbach's Principle of the Common Cause gives this idea helpful expression. Reichenbach's Principle channels the pursuit of understanding thus understood, by indicating not only when a causal account—and so the understanding it funds—is incomplete, but also what would count as extending it. A condition of the possibility of understanding RQFT, on this model of understanding, is that something behaves in RQFT *as causes ought*. To establish this we must, first, extend the notion of cause into the RQFT setting, and, second, investigate whether RQFT constrains causes thus understood to behave as causes ought. We here investigate the contribution to this literature of

Miklos Redei, who supposes that causes behaving as causes ought behave subluminally and in obedience to Reichenbach's Principle (Redei 1996, 29; 1997, 1310).

A set of rough causal expectations—which are, after all, not arbitrary, but derived from our understanding of causal operations in familiar domains—helps orient our extension of causal notions into new domains. These expectations suggest that the question of causal good behavior is settled positively in some situations but problematic in others. For example, where well-behaved causes are taken to act only subluminally, the behavior question is settled positively in situations wherein spatially separated events are statistically independent, but remains problematic in situations where such events are correlated. To answer these open questions requires refining rough causal expectations into an explicit account of cause.

Suppose, then, we were to craft an account of cause in light of which questions about causal good behavior in problematic situations are answered positively because they reduce to questions about causal good behavior in unproblematic ones. In doing so, we would be following a familiar recipe for success in philosophical analysis. But the result will be palatable only if we've respected the sense, built into our rough causal expectations, that the straightforward and settled questions are importantly unlike the difficult open ones. This respect is not a taboo on closing open questions, but a commitment to explain, when our analysis reduces hard questions to easy ones, why what we took to be important differences between the questions makes no difference to the issue of causal good behavior. Only such *respect for open questions* can assure us that the analysis succeeds by extending the core notion of cause rather than changing the subject. A maximally reassuring case for causal good behavior in RQFT will offer an analysis of cause which does not change the subject, and shows that causes thus understood are well-behaved. Any account falling short of maximal reassurance should inspire us not only to revisit the analysis of causation involved, but also, at the next level of abstraction, the model of scientific understanding on which it rests.

In a recent pair of articles (Redei 1996, 1997), Miklos Redei has taken enormous strides toward characterizing the conditions under which RQFT is a safe setting for the deployment of causal talk. His 1996 constructs a RQFT-suitable notion of *causal dependence,* in terms of a formal apparatus associating local events with the projections in algebras of observables the field theory associates with any open, bounded region of spacetime. The paper's key result is that if the algebras of observables associated with spacelike separated regions enjoy the property of C*-independence (a property about which we'll have only slightly more to say later), then no event in one algebra causally depends on any event in the other. Redei takes this result to exorcise the spectre of superluminal causation haunting the violation of Bell-type inequalities in RQFT because that violation occurs for pairs of spacelike separated local algebras which are C*-independent. In light of the result, Redei would have us conclude that the mere violation of Bell-type inequalities is insufficient for superluminal causation. Redei's heartening moral is that Bell-type correlations in RQFT do *not* saddle the theory with gross causal misbehavior (1996, 31). Redei's 1997 complements his 1996 insofar as its main concern is the hospitality of RQFT to causal good behavior, understood as behavior obedient to Reichenbach's Principle. There he offers a criterion for when the correlations a state establishes between elements of distant algebras are *screened off* in that state. The key theorem of this second paper states that if the distant correlations posited by the Minkowski vacuum state are screened off, then the local algebras housing the events distantly correlated are C*-independent. However, this theorem does not settle the most pressing question, according to Redei (1997, 1318), which is whether all, or even *any*, distant correlations can be screened off in the vacuum.

Our main concern here will be the adequacy of accounts of causal dependence and screening off on which rests the relevance of Redei's theorems to the question of causal good behavior in RQFT. We've suggested respect for open questions as a criterion of adequacy for an analysis of cause. In this paper we argue that Redei's analysis fails to show this respect. Our strategy is to translate the Redei-made notions back into the homely setting of Bell-type correlations in non-relativistic quantum mechanics. Our translations reveal that Redei's analysis collapses challenging open causal questions into simple settled ones without addressing their dissimilarities in light of which our rough causal expectations deem one set of questions easy, the other hard.

2. Uncommon Causes We all learned at our mothers' knees to associate the (pure) states of quantum theory with vectors in a Hilbert space, to define quantum observables as operators acting on that space, and to infuse this formalism with empirical content by taking the expection value of an observable O in a state $|\psi>$ to be $<\psi|O|\psi>$. The algebraic approach to QFT turns these lessons on their head. It associates observables with elements of an abstract algebra A, and takes states to be linear functionals mapping observables in the algebra to real numbers which we understand as their expectation values in that state. One advantage of the algebraic formulation is that it enables us to finesse troubling issues concerning the unitary inequivalence of distinct and independently acceptable Hilbert space representations of QFT in curved spacetime (for details, see Wald 1994, §4.5). Every algebraic representation of a state gives rise to a Hilbert space representation (the so-called GNS representation) in the following sense: where A is an algebra of observables and ω a state over that algebra, there exists a Hilbert space H, a map from elements of A to operators on H, and a (cyclic) state $|\xi>$ in H such that $\omega(A) = <\xi| (A)| \xi>$ for all $A \in$ A. An axiom of algebraic RQFT is that such a representation corresponding to a "physically reasonable" vacuum state $|\Omega>$ exists. The map $_{|\Omega>}$ also enables us to identify A with an ordinary von Neumann algebra of Hilbert space operators.

ARQFT for Minkowski space-time associates von Neumann algebras of operators {A(V)} with open, bounded sets {V} in the spacetime. The global algebra is built from these local ones subject to constraints set down in the axioms of ARQFT (for more on algebras and ARQFT, consult Horuzhy 1990). For our purposes, the most significant of these axioms is

Microcausality: if open bounded region V_1 is spacelike separated from open bounded region V_2, then every element of $A(V_1)$ commutes with every element of $A(V_2)$.

Microcausality is meant to suppress blatant action-at-a-distance by ensuring that the local expectation values in no way depend on the performance of distant measurements. This of course does not preclude correlations between distant measurement outcome events, which are the focus of Redei's concerns.

For the purpose of developing his analysis of probabilistic causal dependence between events in ARQFT, Redei identifies local events in an open bounded region with projections in the associated von Neumann algebra, and identifies possible worlds with states over the global algebra. He takes event A to *probabilistically causally depend* on event B—A depends on B, for short—if and only if, for any state $|\phi>$, the probability of A given B in $|\phi>$ is greater than or equal to the probability of A given not-B in $|\phi>$ (with equality only when both are 0). The probability of X given Y in $|\phi>$ is calculated via Lüder's conditionalization:

$$
\begin{aligned}
Pr_{|\phi>}(X/Y) &= <\phi|YXY|\phi>/|Y\phi| \quad \text{if } |Y\phi| \quad 0 \\
&= 0 \qquad\qquad\qquad\quad \text{if } |Y\phi| = 0 \,.
\end{aligned}
$$

The intuition behind this definition (an intuition Redei takes Lewis' counterfactual account of causation to exemplify and uses Stalnaker's possible world semantics to make precise) is that B is a probabilistic cause of A just in case B's occurrence would render A more likely than B's non-occurrence *in every possible world*. Redei takes two local algebras $A(V_1)$ and $A(V_2)$ to be *probabilistically causally independent*—independent, for short—if and only if for no projections A in one and B in the other does A *depend* on B, in the sense just defined. To establish A's failure to depend on B, it thus suffices to produce a world with respect to which A is more likely given not-B than A is given B. And so we have

Redei Independence: $\mathcal{A}(V_1)$ and $\mathcal{A}(V_2)$ are *independent* iff for any A in one algebra and B in the other there's some (global) state $|\phi>$ such that

$$<\phi|BAB|\phi> / |B\phi| \quad < \quad <\phi|B^{\perp}AB^{\perp}|\phi> / |B^{\perp}\phi|, \quad (*)$$

where $B^{\perp}$ is the projection orthogonal to B and associated with the event not-B. Call (*) the *independence criterion*.

The main result of Redei 1996 is

(R) When the algebras associated with spacelike separated regions V_1 and V_2 are C*-independent, they are Redei-independent.

(R) is painlessly obtained. Because V_1 and V_2 are spacelike, microcausality requires their algebras to commute. The Schleider-Roos theorem states that for mutually commuting algebras $\mathcal{A}_1$ and $\mathcal{A}_2$, the condition of C*-independence is equivalent to

The Schleider Property: Where $A \in \mathcal{A}_1$ and $B \in \mathcal{A}_2$, $AB=0 \Rightarrow$ either A=0 or B=0.

Now let us ask, can a non-trivial $A \in \mathcal{A}(V_1)$ depend on a non-trivial $B \in \mathcal{A}(V_2)$? Since V_1 and V_2 are C*-independent, the Schleider property guarantees that $AB^{\perp}$ 0. So for any A, B, there will be some $|\phi>$ which is a simultaneous eigenstate of A and $B^{\perp}$. Using this $|\phi>$ to calculate both sides of the independence criterion, we discover that its r.h.s. is 1 and its l.h.s. 0. So for any non-trivial A, B, the independence criterion holds and no $A \in \mathcal{A}(V_1)$ depends on any $B \in \mathcal{A}(V_2)$. The same argument can be run with A and B interchanged to establish that no $A \in \mathcal{A}(V_2)$ can depend on any $B \in \mathcal{A}(V_1)$. Therefore $\mathcal{A}(V_1)$ and $\mathcal{A}(V_2)$ are independent.

To translate Redei's result into a more familiar setting, consider $H_1 \otimes H_2$, a tensor product of two-dimensional Hilbert spaces. Let $\mathcal{A}_1$ [$\mathcal{A}_2$] be the von Neumann algebra of operators of the form $A \otimes I$ [$I \otimes B$]. In terms of Bohm's version of the EPR setup, we can think of $\mathcal{A}_1$ as the algebra of spin observables associated with one particle and $\mathcal{A}_2$ as the algebra of spin observables associated with the other. Let us apply the Redei-made notion of causal independence to the distant spin algebras. $\mathcal{A}_1$ and $\mathcal{A}_2$ are by construction commutative. They are also, an elementary exercise reveals, possessed of the Schleider property. And that is all it takes to establish that $\mathcal{A}_1$ and $\mathcal{A}_2$ are independent in Redei's sense. For it implies that for any $A \in \mathcal{A}_1$ and $B \in \mathcal{A}_2$, there's a state $|\phi>$ in $H_1 \otimes H_2$ such that $Pr_{|\phi>}(A/B) < Pr_{|\phi>}(A/B^{\perp})$, a state which spoils the Redei-dependence of A on B. The spoiler state is just the tensor product of an A eigenstate in H_1 and a $B^{\perp}$ eigenstate in H_2 (the Schleider property ensuring the existence of such states). Running the argument with A and B interchanged shows that no element of $\mathcal{A}_2$ can depend on any element of $\mathcal{A}_1$. So, again, $\mathcal{A}_1$ and $\mathcal{A}_2$ are causally independent in Redei's sense.

But something odd has gone on. The intuitively problematic question was whether A depends on B *in a state where those events are problematically correlated*, i.e. not rendered statistically independent (screened off) by the state. Redei's analysis of cause enables us to declare A independent of B by procuring a state in which B's occurrence fails to make A's more probable. Such states—notably factorizable $H_1 \otimes H_2$ states, in which observables associated with one particle are probabilistically independent of observables associated with the other—are readily available. So Redei's analysis reduces the open and difficult question of causal dependence in entangled states to the simple and settled one of causal dependence in factorizable states. It does so without addressing the key difference, guiding our sense of which questions are settled and which questions are open, between entangled states and factorizable ones: entangled states establish problematic correlations, factorizables ones don't. The existence of states that don't institute problematic correlations should not close worries about states that do! On Redei's analysis, it does. Redei's analysis changes the subject from state-specific causation to state-independent dependence. But causes understood as state-independent patterns of dependence are uncommon indeed.

Redei has at his disposal a number of strategies for deflecting this criticism. The first emerges as his 1996 closes, when he suggests that the translation we've undertaken from the highfalutin setting to the homely one would be illicit, because the key theorem (R) breaks down in the homely setting:

> the present analysis *does not* apply to the Bohm-Bell system at all since the system $M_2 \otimes I$ and $I \otimes M_2$ [M_2 the von Neumann algebra of 2×2 complex matrices] is not relativistic in the sense that it cannot be considered as $A(V_1)$ and $A(V_2)$ for some (open, bounded) regions V_1 and V_2 in Minkowski space-time (because the local algebras in ARQFT are not type I von Neumann algebras). (39)

Indeed the algebras at issue in ARQFT are type III von Neumann algebras, but our review of the proof of (R) makes plain that the type of algebra at issue is irrelevant to the success of the proof. What earns commuting algebras (be they fancy or homely) Redei-made causal independence is *solely their possession of the Schleider property*, and both the local spacelike-seperated ARQFT algebras and the spin algebras have it. Redei does use special features of Type III algebras to show that "algebras belonging to causally dependent spacetime regions are not independent in the probabilistic counterfactual sense" (35, 39). But this is a result distinct from the one we've translated and, having translated, deflated.

Redei also cites aesthetic grounds in support of his notion of causal dependence. For one, it fits nicely into the received heirarchy of statistical independence conditions in ARQFT (33). For another, it exhibits a "natural constraint" Redei would impose on any weakenings of his notion (which weakenings he, recognizing that his notion might seem overstrong, encourages all hands to pursue). Weaker notions of causal dependence "should distinguish local observable algebras that belong to causally non-independent regions from those that are associated with space-like separated ones" (40). Notice how this natural condition identifies "causally independent regions" with spacelike separated ones! In the context of articulating a notion of causal dependence with respect to which we might pursue a *live* question of whether ARQFT posits such dependence between space-like separated regions, to impose this “natural” condition is, we would suggest, to beg the question.

3. Common Causes A similar subject change afflicts Redei’s reformulation of Reichenbach’s principle of the common cause for ARQFT. Recall that two events A and B are positively correlated iff Pr(AB) > Pr(A)Pr(B). Reichenbach defined a common cause explanation of this correlation as an event C such that

(3.1) $Pr(AB/C) = Pr(A/C)Pr(B/C)$

(3.2) $Pr(AB/\neg C) = Pr(A/\neg C)Pr(B/\neg C)$

(3.3) $Pr(A/C) > Pr(A/\neg C)$

(3.4) $Pr(B/C) > Pr(B/\neg C)$

(3.1) and (3.2) are “screening off” conditions; they imply that information about A [B] does not change the probability of B [A] given $C/\neg C$. (3.3) and (3.4) require the common cause C to be positively relevant to A’s and B’s occurrence so that it can serve as their explanation.

Nothing in Reichenbach’s account precludes what Redei considers to be a non-genuinely probabilistic *common cause*, which he identifies by its logical features as a C such that C entails A and C entails B. Still Redei confines his attention to “truly probabilistic common cause[s],” that is Cs that entail neither A nor B. ARQFT admits global states $|\phi\rangle$—notably, the Minkowski vacuum state—for which

$$\langle\phi|AB|\phi\rangle \quad > \quad \langle\phi|A|\phi\rangle\langle\phi|B|\phi\rangle$$

where $A \in \mathcal{A}(V_1)$ and $B \in \mathcal{A}(V_2)$ are projections, and V_1 and V_2 are spacelike separated open bounded regions of spacetime. Toward determining whether such correlations admit of a common cause explanation, Redei offers the following analysis of “screening off” in a state $|\phi\rangle$:

$\mathcal{A}(V_1)$ and $\mathcal{A}(V_2)$ are *probabilistically screened off* in $|\phi>$ if and only if, for any $A \in \mathcal{A}(V_1)$ and $B \in \mathcal{A}(V_2)$, there exists a C in the common causal past of V_1, V_2 (that is, in an algebra associated with an open, bounded region contained in the overlap of their backward lightcones) such that:

(i) neither $C \subseteq A$ nor $C \subseteq B$

(ii) $|C\phi| \quad 0 \qquad |C^{\perp}\phi|$

(iii) C commutes with A and B

(iv)

a) $<\phi|CABC|\phi>/|C\phi| = <\phi|CAC|\phi>/|C\phi| \times <\phi|CBC|\phi>/|C\phi|$

b) $<\phi|C^{\perp}ABC^{\perp}|\phi>/|C^{\perp}\phi| = <\phi|C^{\perp}AC^{\perp}|\phi>/|C^{\perp}\phi| \times <\phi|C^{\perp}BC^{\perp}|\phi>/|C^{\perp}\phi|$

c) $<\phi|CAC|\phi>/|C\phi| \quad > \quad <\phi|C^{\perp}AC^{\perp}|\phi>/|C^{\perp}\phi|$

d) $<\phi|CBC|\phi>/|C\phi| \quad > \quad <\phi|C^{\perp}BC^{\perp}|\phi>/|C^{\perp}\phi|$

Call such a C a *probabilistic common cause* of A and B.

In the Redei-made analysis of screening off above, (i) assures that we deal only with "genuinely probabilistic common causes" C that stop short of logically entailing their effects, where $C \subseteq A$ iff the projection C has a range contained within the range of A. (ii) assures that (iv)'s Lüder's conditional probabilities, which express Reichenbach's probabilistic conditions on the common cause, make sense. And (iii) is supposed to assure that the analysis remains within the friendly confines of commutative probability theory (1997, 1315). It is unclear to us why (iii) should be necessary when conditional transition probabilities between non-commutative events are precisely what Lüder's rule is designed to handle, but we have no interest in pursuing this point. The "common past" requirement on C that prefaces conditions (i)-(iv) above, by forcing us to countenance only common causes that act subluminally, might seem to beg questions that ought to be left open, especially since Reichenbach himself never imposed such a requirement on his common causes. But again, we have no interest in pursuing this, especially since Redei admits that the central result he proves in his 1997, that C*-independence between spacelike-seperated algebras is necessary for probabilistic screening off of Minkowski vacuum correlations between them, in no way relies on the common past requirement (1997, 1318). So we can weaken Redei-made screening off by relieving it of the common past condition without losing the power of Redei's result. What about the requirement that C, and indeed A and B, all belong to local algebras associated with *bounded* spacetime regions? This too is not necessarily a part of the explanatory intuition behind Reichenbach's Principle, but it too can be weakened while preserving Redei's result. In fact, all Redei needs to assume is that the open set O corresponding to the algebra that contains C is such that both $O \cup V_1$ and $O \cup V_2$ have a nonempty spacelike complement. Hence his result even applies with V_1 and V_2 taken to be the two unbounded 'Rindler' wedges, each the spacelike complement of the other, the corresponding algebras of which sustain Bell-type correlations in the Minkowski vacuum between the particle contents in the two wedges (Wald, 1994, 114-5). (However, to secure this application, Redei definitely *must* relinquish the requirement that C lie in an algebra tied to a region in the causal past of the algebras for V_1 and V_2, since the common causal past of two complementary Rindler wedges is empty!)

Now since Redei's result only establishes a necessary condition for spacelike-seperated events to admit of genuinely probabilistic common cause explanation, the result leaves open the question of whether all or even *any* spacelike seperated events in ARQFT admit of such explanation. But even were this question answered in the affirmative, it would not follow that ARQFT is a safe setting for the deployment of causal talk.

To communicate our residual dissatisfaction with the Redei-made notion of probabilistic common cause, we again translate it into a homely setting. Consider a pair of spin-1 particles described by a composite state residing in a tensor product of two-dimensional Hilbert spaces. Where $\{|v_i\rangle\}$, $\{|w_i\rangle\}$, i = 1 to 3, are complete orthonormal bases for the first and second Hilbert spaces, respectively, let the joint state be any state of form

$$|\psi\rangle = c_1|v_1\rangle|w_1\rangle + c_2|v_2\rangle|w_2\rangle\ ,\ \ |c_1|^2, |c_2|^2 \quad 0 \text{ or } 1.$$

And again let $\mathcal{A}_1$ [$\mathcal{A}_2$] be the von Neumann algebra consisting of elements of the form $A\otimes I$ [$I\otimes B$]. Where $P_{|x>}$ is the projection onto $|x\rangle$, take $A = P_{|v1>}\otimes I \in \mathcal{A}_1$ and $B = I\otimes P_{|w1>} \in \mathcal{A}_2$. We see that A and B are positively correlated in $|\psi\rangle$. For Redei this correlation is probabilistically screened off in $|\psi\rangle$ if there exists a C satisfying (i)-(iv) above. So consider the projection

$$C = (P_{|v1>} + P_{|v3>})\otimes(P_{|w1>} + P_{|w3>})\ .$$

This C neither entails A nor entails B, which satisfies (i). It receives a probability $|c_1|^2$ different from 0 or 1 in $|\psi\rangle$, which satisfies (ii). Sharing an eigenbasis with both A and B, it commutes with both, which satisfies (iii). Calculating (iv) for our A, B, C and $|\psi\rangle$, we find all the relevant equations satisfied. Therefore C is a Redei-made probabilistic common cause of A and B.

Note that since $C|\psi\rangle/|C\psi| = |v_1\rangle|w_1\rangle$, it follows that $Pr_{|\psi>}(A/C) = Pr_{|\psi>}(B/C) = 1$. This reminds us that common causes which are "genuinely probabilistic" in Redei's sense can be deterministic in the sense of issuing their effects with probability 1. If the example we've just run seems thereby to depart from the spirit of Redei's interest in genuinely probabilistic common causes, let

$$|v_1'\rangle = |v_1\rangle + \varepsilon\,|v_3\rangle,\ |w_1'\rangle = |w_1\rangle + \varepsilon\,|w_3\rangle, \quad \varepsilon > 0,$$

and run the example again with $|\psi\rangle$ and C as before, and with $A' = P_{|v1'>}\otimes I$, $B' = I\otimes P_{|w1'>}$. A' and B' will be positively correlated in $|\psi\rangle$ for sufficiently small ε, and C will again serve them as a genuinely probabilistic Redei-made common cause—but this time not one which acts with probability 1 in $|\psi\rangle$.

As with Redei-made independence, Redei-made common causes are distressingly easy to come by, because distressingly state *in*dependent. The key to C's success in both of the above spin-1 examples is that C projects the state $|\psi\rangle$ onto a state that factorizes into a pair of pure states for the particle pair. Therefore probabilities conditional on C in state $|\psi\rangle$ also factorize, satisfying the conditions (iv) in a stroke! C plays this role despite the fact that the composite state is entangled. Insensitive to what the state of the particle pair actually is, Redei's criterion for the existence of a common cause is insensitive to which correlations that state actually establishes. But precisely this sensitivity is what an analysis of screening off needs to respect. For to respect it is to acknowledge why our rough causal intuitions distinguish between the straightforward question of whether screeners off are available for the correlations established by factorizable states and the interesting question of whether they're available for the ones established by entangled states. Redei's analysis of probabilistic common causes misses the point of our worries about the absence of such causes in RQFT in much the same way his account of spacelike causal dependence misses the point of our worries about its presence in RQFT.

4. Conclusion Redei tells reassuring stories about the extent to which common cause stories are available and superluminal dependence prohibited at the cost of requiring us to assert of the homely setting that if superluminal dependence holds anywhere, it holds for factorizable states, and if screening off fails anywhere, it fails for factorizable states. But such notions of dependence and screening off, failing to respect open questions, line up only imperfectly with our expectations. To tell his reassuring stories, Redei must change the subject. Whether it is possible, *without* changing the subject, to tell any reassuring story extending the notion of cause to the setting of RQFT is a question that remains open. The stubbornness with which it remains open—a stubbornness apparent in its resistance to Redei's resourceful analysis—should prompt us to return to the question of exactly how extending the notion of cause into this exotic domain would further respectable cognitive projects.

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