

Block Universe and Shadow Theory: Source, History, and Enacted Temporal Reality

Jeremy Rodgers
Independent Researcher
www.everythingequation.com

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Abstract

A complete physical history does not, merely by being complete, explain how particular relations become locally available, operative and experienced. Shadow Theory distinguishes a nominated source, its physical realization, an embedded organization's records and the relations it actually interprets. We integrate this architecture with relativistic histories while keeping spacetime distinct from the unknown Ground. Relativistic geometry supplies causal routes and proper times; source-readout mathematics determines which missing distinctions obstruct a temporal task and what an attainable completion must retain. Under an explicit enacted-experience constitution, retained predecessor, live contribution and anticipation have different roles within ongoing uptake. Their common availability need not represent simultaneity, and the resulting experience requires no external projector or psychological owner. Target-relative minimal completion also makes the block's explanatory economy precise: an additional actuality selector contributes no required distinction when the declared predictions, records and complete qualifying enactments are preserved. This is a motivated interpretive argument, not a deduction of eternalism.

The physical construction follows the same directed relation from a prescribed spin-chain source through delivery, retention and binding into finite-time use, with an exact accuracy frontier and joint-state robustness bounds. A separate readiness/completion frontier distinguishes classical records from coherent resources for entangled return. A direct theorem on real $1 + 1$ and $3 + 1$ Minkowski space shows that transitivity, translations and specified boost and spatial invariances turn one distinct reciprocal pair into a universal relation, without dilation or global symmetry. Its actuality interpretation requires an independently justified witness. A controlled-process example distinguishes passive local histories from intervention response laws, while an identity-map countermodel preserves the boundary between local incompleteness and a universal deeper-source claim. The result is a conditional explanation of situated temporal reality and sharper requirements for physically realizing its source-readout relations.

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1 The problem: a lived temporal world within a physical history

A history can be complete without being available to any participant within it. The physical description may contain a note's emission, propagation, reception, retention and interpretation at different events. The listener does not receive that description as a whole. Nor is hearing a transition explained by placing two events on a diagram. The explanatory task is to connect the physical relations that actually reach an organization with the differentiated temporal roles they acquire in its ongoing activity.

Shadow Theory addresses this task through a specific architecture. Source and readout are complementary structural and presentation roles within one reality; the readout includes instruments, bodies and records, rather than an image displayed to an observer outside reality. Its mathematical core asks which relations descend to a nominated representation, what distinctions a sufficient completion must preserve, and when projected dynamics close [24–26, 28, 29]. Its philosophical account distinguishes the unknown Ground and unsplit unity from any working source model. Its enacted-experience proposal identifies complete qualifying organization with experience rather than appending a second recipient to an otherwise finished process [21, 36, 37].

A block interpretation supplies a natural temporal setting for this architecture. Events have temporal and causal locations; there is no further universal present moving through the description. An embedded organization can still change, learn and act. Its earlier and later stages differ in what they receive, retain and can do. Those differences are real parts of its history, not appearances generated by a second time. Relativity constrains this interpretation through causal order and the absence of an invariant global simultaneity convention, but does not by itself prove eternalism [17, 43, 44].

The proposed integration has two directions. Relativistic histories sharpen Shadow's realization claims: a physically admissible readout needs routes, clocks, preparation, finite storage and a time at which it can be used. Shadow sharpens the block account: it identifies the target-relative distinction that must reach a participant, follows that distinction into an actual temporal operation, and gives a conditional account of its experiential significance. It also gives explanatory economy an exact target-relative meaning: an additional actuality selector is unnecessary to minimal completion when it preserves the declared predictions, records and qualifying enactments. A retained predecessor, live contribution and anticipated continuation can participate together without representing their source events as simultaneous. Interpretation can proceed before a sequence ends. Mutual strengthening here means explanatory integration, sharper physical realization requirements and formal consequences of explicit premises. It does not mean reciprocal experimental confirmation of eternalism and Shadow's deeper-source ontology.

The physical argument is more specific than a general observation that memory is limited. For two independently prepared source features, a solved delivery and memory program fixes the joint code at the local operation. Exact optimization then gives a necessary accuracy and retention condition for a nominated directed relation. Binding interventions preserve stored information while changing the relation actually executed. A separate coherent-completion benchmark tests a stronger quantum task under different preparations. These are concrete constraints on how a source becomes usable organization.

Two further issues must be resolved rather than merged into this construction. First, a global co-reality relation differs from causal accessibility or temporal interpretation. A reciprocal-pair theorem identifies strong consequences of particular invariance and transitivity premises, but its physical witness needs independent justification. Second, loss between a history and an observer does

not establish loss between a deeper source and the physical history. The latter claim must confront a source-complete identity realization and the strongest existing physical witnesses. Keeping these distinctions explicit makes the positive integration stronger: its explanatory work is carried by specified relations and operations, rather than by exchanging the meanings of “source,” “present” or “real.”

2 The architecture: Ground, realization, history and presentation

2.1 Different explanatory roles within one reality

The unknown Ground is not a variable at the beginning of a physical equation. It names the proposed unconditioned basis of reality, for which a differentiated source model is not claimed to be an exhaustive description. The unsplit, denoted here by U , expresses unity prior to the source–readout distinction. This priority concerns explanatory dependence, not an earlier event before physical time. A nominated source, by contrast, is a specified mathematical object with an admitted state space, symmetries and realization rules. The philosophical commitment is that concepts formed within differentiation do not exhaust that basis; this is not a theorem of formal incompleteness. The Ground, unsplit and nominated source are therefore not interchangeable [37, 38].

This distinction matters for both physics and consciousness. Fundamental awareness is a provisional quality attributed to the Ground, not a cosmic subject watching physical events. It is not first created by a successful decoder. Physical organization is proposed to determine the form and boundaries of localized experience, not to manufacture the ontological basis from which the account starts. This is a philosophical commitment. Its reason is to seek one basis for physical reality and experiential presence while locating their differentiated forms in actual organization. Neither common constitution nor a common basis entails one universal subject.

The scientific burden falls on the nominated realization. A source may be an ordinary quantum state of a system and its environment, a gravitational bulk model, or a pregeometric formation package. Distinct source states must first be reduced by declared gauge and redescription equivalence. Calling two coordinate descriptions different does not establish a physical distinction. Nor does giving a formal space the name “source” establish that physical reality needs a structure beyond spacetime [24, 27, 29].

2.2 Where the spacetime construction enters

The source-to-readout architecture types its global realization as a partial, potentially set-valued relation

$$\text{Read}_\Omega : S_0 \rightrightarrows \text{Comp}_{T_1} .$$

The parameter Ω here belongs to a formation model, not an exact mathematical name for the Ground. Comp_{T_1} consists of coupled compatible physical readouts: quantum sectors, records, geometric and matter structure, and their consistency conditions. Admission and compatibility can fail, and an admitted source need not determine a unique readout without further boundary or selection data [33, 37].

Fix a physically admitted branch and sufficient realization conditions $\mathcal{L}$. A representation of its

physical history then has the form

$$F : \mathbf{S} \longrightarrow \mathcal{H}_{\mathcal{L}}, \quad \text{or} \quad F(s, dh) \quad (1)$$

when the appropriate realization is a probability kernel. This is the history component of a nominated realization, not an assertion that every source produces one classical block. Quantum alternatives may require a process or an event/branch-relative account; no measurement interpretation is settled by writing $h \in \mathcal{H}_{\mathcal{L}}$. Where a complete actual history is admitted, a block interpretation concerns the existence of its actual events. It does not identify that history with the Ground.

Shadow's broader physical proposal is that the coupled physical order is realized from a common source structure and need not exhaust the distinctions admitted by that source. This is a hypothesis about F , not only about local presentation. Its positive motivation is unification: one admitted construction must constrain quantum sectors, objective records, geometry and compatible dynamics together. A source model earns explanatory advantage when independently fixed structure derives compatibility or discriminating responses, rather than adding a separate hidden coordinate to fit each result [27, 28, 30, 37]. A block history can be the actual physical realization of those constraints without being the Ground. This motivates retaining the richer-source hypothesis; the physical witnesses determine how much of it is established in each model.

An observer O is an organization within h . Its collection and retention program π , at local occasion τ , induces a different map or instrument,

$$q_{O,\tau,\pi} : \mathcal{H}_{\mathcal{L}} \longrightarrow Z_{O,\tau,\pi}. \quad (2)$$

The local code is a physical record, not yet a complete specification of interpretation. A realized operation uses the code with native source bindings and learned organization. The experiential proposal identifies a complete qualifying enactment with experience; it does not add another projection onto an internal screen. These relationships are summarized by

$$\mathbf{S} \xrightarrow{F} \mathcal{H}_{\mathcal{L}} \xrightarrow{q_{O,\tau,\pi}} Z_{O,\tau,\pi}, \quad \text{qualifying actual enactment} \equiv_{\text{constitution}} \text{experience}.$$

The observer, its code and its use all occur within the physical realization. The same physical history can be a readout relative to F and a source relative to q without either role revealing the unknown Ground.

The broader schema $L = \Omega_{T1} \Delta \partial[L]$ records the programme's Tier-1 completion/readout discipline. Ω_{T1} is the typed public completion/readout operator; it is not the Ground, a universal solver, or automatically the branch map F . The monograph's Read_{Ω} and a specific history map have their own types and hypotheses. In the present construction the schema earns content only when a target, an admitted realization and a physically attainable completion are specified. It does not itself prove the existence of a deeper source [31–33, 37, 38].

In the physical models below, scalar channel parameters are defined locally; they are not the access map $q_{O,\tau,\pi}$. In particular, the spin-chain frequency Ω is unrelated to the formation-model parameter in Read_{Ω} . The unsplit $\mathbf{U}$, actual uptake U_A and a unitary operator U likewise have distinct types.

2.3 What a target-relative readout theorem establishes

Let $q : \mathcal{H} \rightarrow Z$, with $Z = \text{im}(q)$ the admitted readouts, and let $f : \mathcal{H} \rightarrow A$ be a nominated target. The descent condition is exact:

$$\exists \bar{f} : Z \rightarrow A \text{ with } f = \bar{f} \circ q \quad \Longleftrightarrow \quad q(h) = q(h') \Rightarrow f(h) = f(h'). \quad (3)$$

Necessity follows by substitution; sufficiency defines $\bar{f}$ by the common value on each nonempty fiber. A coarsest sufficient extension is

$$E_f = \text{im}(h \mapsto (q(h), f(h))).$$

Restrict an extension to its realized image: if $e : \mathcal{H} \twoheadrightarrow E$ and $\pi e = q$, $ge = f$, the unique comparison map is $v : E \rightarrow E_f$, $v(y) = (\pi(y), g(y))$. It satisfies $ve = (q, f)$. This is the target-relative completion of the canonical theory, not a new theorem about every representation [25, 26]. Physical completion asks a further question: can the needed distinction be transmitted, retained and used by the specified occasion?

For a dynamical readout W , autonomous evolution exists only when readout equivalence is preserved by the admitted source evolution. In a linear split, unresolved initial conditions and coupling produce the exact projected memory and forcing terms; neither stochastic noise nor a Markov approximation is needed for that fact [28]. This becomes explanatory within a history when an apparently ready local state can later receive a distinction retained elsewhere. The participant's display is then insufficient for that continuation, although a more complete physical state may close perfectly well.

The same construction makes explanatory economy precise. Consider admitted history-selector pairs $x = (h, a) \in \tilde{\mathcal{H}}$ and let $b(x) = h$ forget an additional actuality selector. Compare exactly the history domain $\mathcal{H} = b(\tilde{\mathcal{H}})$. Declare a family of targets $\Theta = (T_i)_{i \in I}$, comprising the physical prediction laws for specified preparations and interventions, records, and complete qualifying enactments relevant to the explanation. Suppose the retained description and every declared target factor through b :

$$\tilde{q} = q \circ b, \quad T_i = t_i \circ b \quad (i \in I).$$

Then the joint-image completions coincide:

$$\text{im}(\tilde{q}, \Theta) = \text{im}(h \mapsto (q(h), (t_i(h))_{i \in I})). \quad (4)$$

Every element on either side comes from an admitted pair on the left or its image under b on the right. The selector therefore contributes no distinction required by this minimal completion. The factorization conditions must be established for the particular comparison, or treated explicitly as conditional; they do not hold for every rival ontology by default. A selector that changes the admitted histories, prediction laws, actual records, qualification or complete enactment requires a different assessment.

For experiential targets, equality of complete qualifying enactments gives experiential equivalence only under the complete-enactment identity introduced in Section 4, with the same independently justified qualification. Equal reports or stored information are insufficient. Removing a selector from this target-relative explanation does not prove its nonexistence. Nor does erasing an additional variable erase indexed actuality relations definable from the retained geometry. Inferring an exhaustive ontology from minimal completion requires a further principle of ontological economy.

3 Relativistic history and the case for the block interpretation

3.1 Geometry, change and actuality

For a timelike worldline, proper time satisfies $d\tau^2 = dt^2 - \|d\mathbf{x}\|^2/c^2$ in inertial coordinates. It times physical processes along that worldline, rather than selecting a simultaneous universe-wide

state. A spatially extended organization occupies a worldtube and uses transported signals and local clock conventions. Relativity supplies invariant causal relations and proper durations, while simultaneity between spacelike events depends on an inertial frame. It does not select a universal present hypersurface. An eternalist interpretation takes actual events at their different temporal locations to belong to reality without an additional activation process. This is an economical reading of the spacetime relations used by the theory, rather than a deduction from the word “history.” Its appeal is that one physical organization accounts for change, clocks and records without a further present selecting which region exists.

Section 2, especially (4), gives this economy a precise Shadow contribution: where the stated target equivalences hold, a history-based explanation needs no additional activation selector. This does not prove the selector nonexistent or remove indexed actuality relations definable from geometry.

The cost and the alternatives are real. A spacetime model represents events; the step from representation to tenseless existence is interpretive, and not every becoming account satisfies the comparison premises. A relational-becoming account can use invariant past-definiteness without selecting an absolute simultaneity slice. Myrvold’s relativistic quantum becoming extends such relations to regions and hypersurface-indexed state/chance descriptions, preserving the significance of nonseparable quantum states without deriving reciprocal actuality [17, 43, 44]. The block branch is defended here for this explicit economy and its fit with a single physical history, not by denying this alternative a coherent formulation.

Geometry, determinism, time-reversal symmetry and eternalism answer different questions. Determinism concerns uniqueness from adequate data; a complete actual history alone does not establish that uniqueness. Time reversal concerns transformed solutions of laws, not which events exist. Physical change is a difference along the history: propagation, memory writing and deliberation occur at ordered events. No outside clock is needed to make those differences occur. Conversely an indeterministic history law can have one actual complete outcome history without its earlier stages having determined all later outcomes.

3.2 A precise reciprocal-pair implication

Let $R(p, q)$ be one fixed relation between events, interpreted conditionally as “ q is co-real relative to p .” It is not an access relation or an observer-indexed family. In real $1 + 1$ Minkowski space write

$$B_\ell(t, x) = \left(\frac{\ell + \ell^{-1}}{2}t + \frac{\ell - \ell^{-1}}{2}x, \frac{\ell - \ell^{-1}}{2}t + \frac{\ell + \ell^{-1}}{2}x \right), \quad \ell > 0.$$

These are all proper orthochronous boosts, with $c = 1$. Spatial reflection is $P(t, x) = (t, -x)$.

Theorem 3.1 (Reciprocal pair under relativistic symmetries). *Assume that R is transitive and invariant under every translation.*

1. *In real $1 + 1$ Minkowski space, also assume invariance under every B_ℓ and spatial reflection.*
2. *In real $3 + 1$ Minkowski space, instead assume invariance under all proper spatial rotations and proper orthochronous boosts.*

If $p_0 \neq q_0$ satisfy both $R(p_0, q_0)$ and $R(q_0, p_0)$, then $R(p, q)$ for every pair. Reflexivity follows from these assumptions; dilation, global symmetry, continuity and measurability are unnecessary.

Proof idea; complete proof in Appendix A. The mutual core $H = \{v : R(0, v) \wedge R(v, 0)\}$ is an additive subgroup containing a nonzero displacement. In $1 + 1$, reflection gives a nonzero pure-axis vector. Differences of opposite boosts generate the other complete axis because $\ell - \ell^{-1}$ ranges over all real numbers. A fixed nonzero boost then generates the first complete axis. Thus $H = \mathbb{R}^2$. In $3 + 1$, a spatial rotation places the displacement in a time–space plane; a proper rotation through π supplies reflection within that plane. The $1 + 1$ argument gives the full time axis, and boosts along each spatial axis generate the remaining components. Translation then makes R universal. $\square$

The result is a direct Stein-type consequence with a particularly transparent mutual-core proof. Stein’s fixed-length spacelike argument already removes the no-unit/dilation stipulation [44, p. 150]; no historical priority for the general geometric implication is claimed. The direct $1 + 1$ and $3 + 1$ implications have independent Lean formalizations that do not invoke the dilation-based classification. The $3 + 1$ module uses coordinate-axis boosts and the three proper spatial half-turns displayed in Appendix A; full proper-orthochronous Lorentz invariance is a stronger sufficient package. No complete $3 + 1$ classification is inferred from these proofs.

The stronger assumptions used in a separate six-way $1 + 1$ classification must not be imported unnoticed. That classification assumes reflexivity and transitivity, translation/boost/dilation/reflection invariance and an ordered field with positive square roots. It yields identity, chronological past or future with identity included, causal past or future, and universality. A fixed positive proper-interval threshold gives an invariant transitive past relation outside that list when dilation is omitted. It has no distinct mutual pair, so it does not refute Theorem 3.1. The classification and the reciprocal implication therefore have different scopes.

3.3 Why the ontological bridge is substantive

Theorem 3.1 proves universality of a relation under its assumptions. Applying it to actuality requires independent reasons for the meaning of R , its invariances and transitivity, and one distinct reciprocal witness. A process having duration, a later state depending on an earlier state, or two contributions constituting one interpreted transition does not by itself supply that witness. Determination, constitutive dependence and reciprocal actuality are different relations.

Reciprocity can be proposed as a metaphysical branch: if actuality is a single homogeneous relation of mutual belonging, a single actual relation spanning distinct events may motivate mutual membership. The theorem makes the cost of this branch exact. Yet treating an actual process as the witness already commits one to that reading of belonging; the process’s occurrence cannot independently establish it. We therefore do not add reciprocal actuality as a universal axiom of Shadow Theory. The block interpretation remains independently defended, and the conditional branch states what stronger consequence follows if the bridge is earned.

Invariance of a fixed relation is also stronger than covariance of an indexed family. For a future-directed unit velocity u , let $R_u(p, q)$ mean $u \cdot (q - p) = 0$. Each fixed relation is a nonuniversal equivalence relation with reciprocal spacelike pairs. The family is covariant when u, p, q are transformed together, but a fixed R_u is not boost invariant. Apparatus, observer and process-window relations require the same distinction. No appeal to generic covariance licenses the theorem for local access.

Without boosts, equal coordinate time is a nonuniversal reciprocal relation; without transitivity, equality-or-spacelike separation is another. Without translations, equal Minkowski norm relative to a selected origin survives Lorentz symmetry. In $1 + 1$, omitting reflection permits a null-line equivalence invariant under all boosts. These countermodels show exactly which mathematical assumptions carry the universality implication. None of them makes global co-reality entail global observation.

4 Enacted temporal experience and the absence of an external owner

4.1 A constitutive proposal and its explanatory work

A complete history gives the physical location of an interpreting activity. It does not, by that fact alone, explain the relation between activity and experience. The enacted-scaffolding proposal supplies a substantive constitution: complete qualifying actual organization is the experience, including its character, rather than a mechanism producing an additional experiential object for a separate owner [21, 36].

For the nominated adult case, the relevant roles are actual reception or internal retrieval D , interpretation through operative organization I , consolidation C , retention sufficient for its use M , and actual uptake U_A . Uptake means that the represented relation participates in ongoing recognition, relating, appraisal, orientation or response. Dormant accessibility does not establish that participation. The roles need not be serial modules and uptake need not be verbally acknowledged. Later addressed retrieval R_{later} is a further operation, not a universal condition of the earlier experience.

Let $K(A, J)$ be the complete actual enactment of a nominated unit over activity J , including bodily/evaluative implementation, source binding and relevant causal/developmental embedding. The constitutive branch used for the temporal application can be expressed as

$$\text{Qual}_{\mathbb{E}}(A, J) \implies K(A, J) \equiv \text{the corresponding experience}, \quad (5)$$

Here the application is explicitly conditional on an independently admitted experiencing embodied adult and the complete-enactment identity for that person's ongoing organization. Qualification is not defined as passing the finite task below, derived from the universal experiential-contributor rule, or inferred from a universal relational-development condition. The application is anchored in the nominated adult; it is not a new universal admission law. In the adult application the displayed interpretive roles are necessary parts of that account. They are not asserted as an exhaustive admission test for every possible subject. The complete constitution is a philosophical premise, while whether these operations belong to this person's actual activity is a separate realization question.

The premise has positive explanatory motivation. It locates the temporal differentiation in the same activity that receives, retains and uses the relation, avoiding a second observer that would

itself need to interpret the result. It makes a binding difference relevant to temporal character without assuming a visible sequence replayed to an inner witness. Fundamental awareness, within the ontology, is not produced when a computation succeeds; organization is proposed to articulate particular experience. This answers a constitutive question conditionally, rather than deriving awareness from a channel theorem. A critic may accept every operational mechanism and reject the identity. The disagreement concerns what constitutes experience, not an operation omitted from an otherwise accepted complete identity.

The analytical projection $\mathcal{T}(K)$ selects source references and temporal roles. It is not a complete map of felt character. Equal reports, equal stored bits or equal values of $\mathcal{T}$ do not establish equality of complete experience. A finite transducer can implement a component of the required relation without constituting a person or a complete experiencing occurrence. The embodied adult is the nominated boundary here; no terminal output register selects a subject. Nested contents and overlapping episodes likewise do not determine nested or larger bearers.

4.2 Temporal roles within continuing activity

Consider notes emitted at timelike-separated source events. A retained contribution can participate as predecessor, a newly received contribution as live input, and a learned expectation as anticipated continuation. These are three modes of organization at an occasion, not three simultaneous source events. In particular,

$$\text{available}(r_C, \tau) \wedge \text{available}(\ell_E, \tau) \text{ is compatible with } \hat{C} \prec_{\text{represented}} \hat{E}.$$

The physical carriers are jointly usable; their represented occurrences remain ordered. The organization need not wait for a whole melody before taking up a transition. An anticipation is a present predictive disposition about a possible continuation, not a signal received from the future. Different complete histories can share the same local prefix and current expectation while later supplying different notes.

This distinguishes a succession of physical states, an order record, successive experiences, and an experience whose content is succession. An unordered bag of features does not specify their roles. An ordered archive can still remain unused or be bound to a different stream. The physical construction must therefore follow the same distinction through delivery, retention, source binding and operative use. The source-to-use theorem below does exactly this for a declared directed-feature task; it does not infer all phenomenal character from an accuracy score.

Temporal organization is also selective without being illusory. The causal past contains possible influences never intercepted or retained. The actual retained code can shrink through forgetting, so its available-information algebra need not increase monotonically. An ideal accumulated transcript is a different physical resource. Reversible dynamics and proper-time order alone do not establish an asymmetry between records of the past and anticipation of the future. Prepared ready registers, localized writing routes, retention and a specified statistical ensemble supply that asymmetry in the models here. Independently prepared future features are not available through an uncharged correlated context. Time reversal changes those preparations rather than making the same ready experiment write an ordinary future record.

Prior causes are not all included in current experience merely because they contributed to its history. For an independently qualifying adult, continuations preserving the complete relevant enacted organization of an earlier occurrence preserve that occurrence under the identity premise. Later retrieval or loss cannot retrospectively supply or erase it. A later loss changes later availability;

a later reconstruction is another current activity representing the earlier one as past. This common-prefix invariance concerns complete organization, not merely an unchanged task-level code.

4.3 Experience without psychological appropriation

Practical bodily indexing, source attribution and psychological ownership must be distinguished. The organization can locate a sound relative to the body, protect bodily function and retain learned discriminations without organizing every occurrence around an independently existing owner. The psychological appropriation “this is happening to me” adds a relation to a self-story; it is not identical to every physical use of an index for this body.

Accordingly the account permits experiential hearing without appropriation, provided the requisite actual organization remains. Removing ownership is not removing sensation, operative retention, learned discrimination or uptake. Nor is it a claim that the complete character remains identical: appropriation can itself change what is experienced. The point is that a temporal transition need not cease to be experienced when this particular self-related organization is absent. No empirical test for complete absence of appropriation is derived from that conceptual distinction.

This matters to the block integration. Psychological continuity can amplify passage through remembered identity and anticipated personal futures, but temporal succession need not be generated by that ownership. The retained/live/anticipated differentiation already operates within the physical history. Its experiential constitution does not require a self to move between temporal locations or an external awareness to scan them. Such scanning would merely relocate the explanatory demand for the present to a new parameter.

4.4 Admission, development and the scope of the proposal

Published SPC-2 specifies perspective admission, complete endogenous predictive content and process continuation through A1–A3 on a certified realization [35, Sections 17.2–17.4]. The enacted-scaffolding account and its actual-uptake refinement are not proved equivalent to those laws. Developed reasoning and human language are central to the adult conceptual case; broader structured discrimination and inference is a different criterion from human linguistic competence. Interpreting an occurrence does not require explicitly defining or reporting experience. Preconceptual experiential organization is not excluded by the adult example.

One stronger formative requirement makes every experiencing activity depend on a contributor that already experiences. Appendix B separates a necessary contributor condition from a biconditional admission recipe. Both admit the empty assignment and exclude any nonempty assignment on well-founded experiential ancestry; the finite fixed-point classification concerns the biconditional recipe. A nonrecursive alternative requires actual relational formation of operative scaffolding without experiential admission of each contributor. That is a scoped constitutive variant, not an established universal law or a replacement for SPC-2. The adult temporal application assumes a justified qualifying person and their actual interpretive history; it does not derive their admission by calling them admissible. These distinctions preserve the constructive explanation without reinstating an inconsistent universal origin rule.

Hartle’s information-gathering and utilizing systems and Ismael’s embedded perspectives already explain much about local memory, prediction and temporal presentation [10, 12, 13]. Shadow’s addition is not the discovery of these roles. It is the exact target/completion question, the physical account of attaining that completion at an occasion, and the explicit constitution under which the

qualifying organization itself is experiential. These contributions can be assessed separately: the resource theorem can be confirmed while the complete identity, unit boundary or Ground-awareness premise remains disputed.

5 A prescribed source: local absence and coherent return

A source-readout claim becomes physically informative when dynamics, preparation and spatial ports are specified before loss is assessed. An engineered perfect-transfer spin chain provides such a source [6]. Its local state becomes exactly ready while the omitted environment retains the input, and the same fixed dynamics later return that input. The construction therefore distinguishes physical preservation from local possession and fixes the resources needed for completion.

5.1 Dynamics, preparation and resources

Let $N \geq 3$ be odd, $\Omega > 0$, and $\hbar = 1$. There are N qubits, with site 1 the nominated readout S and sites $2, \dots, N$ the environment E . Put $n_j = |1\rangle\langle 1|_j$ and

$$H = \sum_{j=1}^{N-1} \frac{J_j}{2} (X_j X_{j+1} + Y_j Y_{j+1}) + B \sum_{j=1}^N n_j, \quad J_j = \frac{\Omega}{2} \sqrt{j(N-j)}, \quad B = \Omega N. \quad (6)$$

The environment starts in $|0 \cdots 0\rangle$. Site 1 receives an unknown qubit or half of an entangled pair with a reference R . After preparation the Hamiltonian stays fixed. There is no input-dependent controller, switching sequence or after-cut access to the preparation label. Coupling calibration, ready preparation, an input-independent clock/phase reference, final measurement and retention of its output are counted resources. Incompatible tests refer to separate preparations.

This is a finite nonrelativistic quantum model. Nearest-neighbor coupling supplies a physical communication route, not an exact relativistic light cone. Fabricating and calibrating it is an experimental obligation; the mathematical Hamiltonian does not certify a laboratory apparatus. Bohmian and scalar-current record constructions have separate statistical and ontological assumptions; none is needed for the quantum-channel calculation here.

The vacuum can be a stable ready state. On two adjacent spins, the exchange term obeys $h_j \geq -J_j(n_j + n_{j+1})$: in the one-excitation sector its eigenvalues are $\pm J_j$, and in the other sectors it vanishes. Therefore

$$H \geq \sum_j (B - J_{j-1} - J_j) n_j, \quad J_0 = J_N = 0.$$

Since $J_j \leq \Omega N/4$, every displayed coefficient is positive. The vacuum is the unique zero-energy ground state. Loading an input still costs preparation resources; no finite-temperature preparation guarantee follows.

Proposition 5.1 (Exact ready cut and return). *For the prescribed source, $T = \pi/\Omega$ is a time at which S is exactly the pure ready state for every input. The input resides at site N up to a known phase. At $2T$ the original input returns exactly to S , including its entanglement with an untouched reference.*

Proof. Excitation number is conserved and the vacuum is fixed. Write $|j\rangle$ for one excitation at site j . In this sector $H = BI + \Omega J_x$, with spin $J = (N-1)/2$. To obtain the amplitude without

assuming the result, identify $|j\rangle$ with a normalized symmetric state containing $j - 1$ up spins among $N - 1$ auxiliary spins. Then J_x is half the sum of their X operators. Independent rotations of the lowest-weight product give

$$c_j(t) = e^{-iBt} \sqrt{\binom{N-1}{j-1}} [-i \sin(\Omega t/2)]^{j-1} [\cos(\Omega t/2)]^{N-j}. \quad (7)$$

Thus $\alpha|\text{vac}\rangle + \beta|1\rangle$ evolves to $\alpha|\text{vac}\rangle + \beta \sum_j c_j(t)|j\rangle$. At T only c_N remains. At $2T$ only c_1 remains, with phase $e^{-i2\pi N}(-1)^{N-1} = 1$. Linearity proves the statement for mixed and reference-entangled inputs. At T , in particular, the full state factors as $|0\rangle\langle 0|_S \otimes \rho_{RE}(T)$. $\square$

The factorization is stronger than equality of two local measurement statistics. It also identifies an ordinary quantum environmental completion: nothing in this witness requires an exotic substrate. Braunstein and Pati's no-hiding theorem already establishes a more general unitary information-localization result [2]. The added work is the timed, resource-counted source and its exact comparison below.

5.2 Exact finite-horizon insufficiency of the current physical resource

For binary preparations $i = 0, 1$, set

$$p(u) = |\cos(\Omega u/2)|^{2N-2}, \quad \rho_0(u) = |0\rangle\langle 0|, \quad \rho_1(u) = (1 - p(u))|0\rangle\langle 0| + p(u)|1\rangle\langle 1|.$$

Let $D(\rho, \sigma) = \|\rho - \sigma\|_1/2$. At $s < t$, a proposed physical update has only the current qubit, independent ready ancillas and a common completely positive trace-preserving (CPTP) map. It has no source-correlated archive or incoming carrier. With $p = p(s)$, $q = p(t)$ define

$$e(p, q) = \inf_{\mathcal{R}} \max_{\text{CPTP } i=0,1} D(\rho_i(t), \mathcal{R}(\rho_i(s))).$$

Theorem 5.2 (Prescribed-source finite-horizon deficit). *For $p, q \in [0, 1]$,*

$$e(p, q) = \frac{[q - p]_+}{2 - p}. \quad (8)$$

Proof. Dephasing the candidate output preserves the diagonal targets and cannot increase trace distance. A candidate reduces to stochastic rows $r_0, r_1 \in [0, 1]$, the excitation probabilities on inputs 0 and 1. Its errors are r_0 and $|(1 - p)r_0 + pr_1 - q|$. For $q \leq p$, choose $r_0 = 0$, $r_1 = q/p$ when $p > 0$; the zero case is immediate. For $q > p$, both errors at most e imply $r_0 \leq e$, $r_1 \leq 1$ and hence $e \geq q - p - (1 - p)e$. Thus $e \geq (q - p)/(2 - p)$. The choice $r_0 = e$, $r_1 = 1$ attains equality and defines a valid measure-and-prepare channel. $\square$

For example $p = 1/2, q = 1$ requires error $1/3$, compared with the generic half-distance lower bound $1/4$. At the ready/return pair $p = 0, q = 1$, the optimum is the familiar half-distance value $1/2$. The calculation is an elementary statistical-experiment deficiency problem, close to randomization and quantum sufficiency theory [3].

The target matters. For $p > 0$, the two density-matrix coordinates are distinct; an arbitrary numerical function on their image can invert them. Equation (8) excludes a common *physical* CPTP postprocessing of the current qubit, not every mathematical forecast from exactly known ensemble

parameters. At $p = 0 < q$ the current states coincide, so even a common single-valued forecast from the current state fails uniformly across the two preparation-conditioned future laws. A correct marginal forecast for one fixed mixture of preparations is never refuted. This distinction prevents physical resource insufficiency from being inflated into universal coordinate nonclosure.

5.3 Deadlines, communication and error budgets

Fix the largest coupling at g . For odd N ,

$$g = \frac{\Omega}{4} \sqrt{N^2 - 1}, \quad T = \frac{\pi \sqrt{N^2 - 1}}{4g}. \quad (9)$$

The out-and-back time grows linearly with chain length at bounded coupling. Holding Ω fixed while increasing N would increase the strongest coupling, not establish arbitrarily fast access.

After the ready cut, let $t = T + \delta$, $0 \leq \delta \leq T$. The endpoint amplitude magnitude and population are

$$c(\delta) = \sin^{N-1}(\Omega\delta/2), \quad q(\delta) = c(\delta)^2, \quad e(0, q(\delta)) = q(\delta)/2. \quad (10)$$

The channel from the *original input*, equivalently its encoded environment at T , to this later endpoint has phase-corrected entanglement fidelity

$$F_e(\delta) = \frac{(1 + c(\delta))^2}{4}. \quad (11)$$

Indeed its amplitude-damping Kraus operators are $|0\rangle\langle 0| + c|1\rangle\langle 1|$ and $\sqrt{1 - c^2}|0\rangle\langle 1|$, and $F_e = \sum_a |\text{Tr } K_a|^2/4$. The known phase is absorbed in the calibrated final measurement. This is not a channel from the ready state $S(T)$ alone.

The classical-memory benchmark $F_e > 1/2$ becomes detectable after

$$\delta_{\text{crit}} = \frac{2}{\Omega} \arcsin[(\sqrt{2} - 1)^{1/(N-1)}].$$

This is a witness threshold, not first arrival or first existence of quantum information. The spin model has small finite-time tails; the relativistic field construction in Appendix C supplies the separate exact-locality example.

If actual binary states at s, t are uniformly within η_s, η_t of their ideal states, contractivity and two triangle inequalities give

$$e_{\text{actual}}(s, t) \geq [e(p, q) - \eta_s - \eta_t]_+. \quad (12)$$

For $H' = H + V$, $\|V\| \leq \nu$, Duhamel's identity gives $\|U'(u) - U(u)\| \leq u\nu$. A purification argument then bounds $\eta_u \leq \eta_0 + u\nu$ for preparation error η_0 , giving $e_{\text{actual}} \geq [e(p, q) - 2\eta_0 - (s + t)\nu]_+$. Timing and readout errors need additional calibrated margins. These are conservative sufficient bounds; fitting all errors to the same return data would not independently justify them.

6 From physical delivery to an operative temporal relation

A temporal interpretation depends on which source relations actually reach its operative organization. Prescribed delivery, retained predecessor, live contribution and a directed update can be connected in one resource-accounted program. The result is a necessary resource condition for a nominated functional interpretation, with a conditional scheduled ideal-interface realization. It does not classify the detached device as an experiencer.

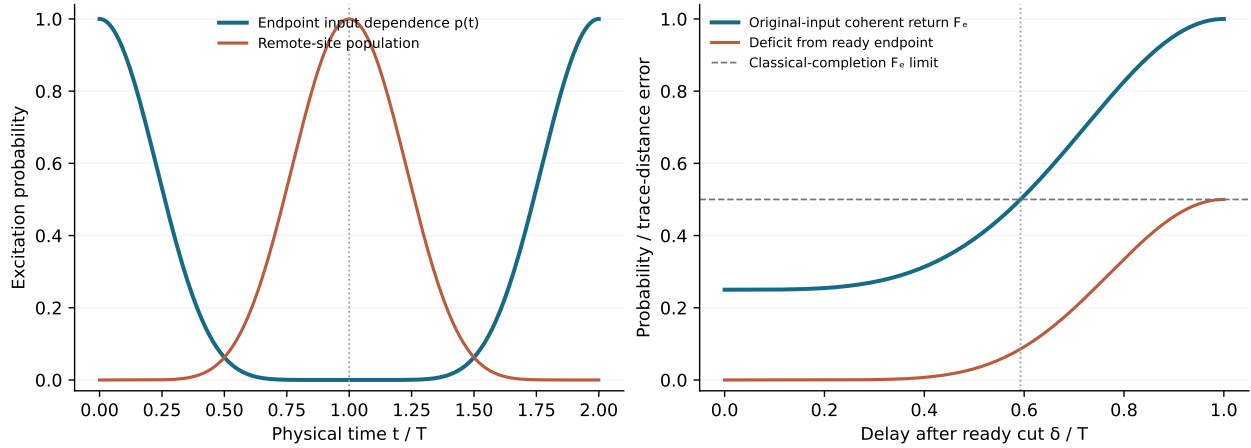


Figure 1: One prescribed five-spin source. Local population and coherent-return fidelity vary while the global unitary source retains the input. The exact physical-postprocessing deficit is calculated from the current and later populations. The classical-completion threshold is distinct from the location or existence of stored information. Curves are analytic model predictions, checked against matrix evolution; they are not experimental data.

6.1 One declared source-to-record program

Let a, b be independent uniform binary features in two calibrated source slots, with a the predecessor and b the later contribution. Choose timelike-ordered source events if a relativistic embedding is used; the slot schedule is local apparatus structure, not a universal simultaneity slice. Include repeated features in the ensemble. The target $D = b - a \in \{-1, 0, +1\}$ is directed feature change under fixed provenance, not an estimate of which source emitted first. The full ordered pair, equivalently the four-valued extrapolation code $G = 2b - a$, is a stricter target. No unordered-pair label or preparation archive is free side information. The surrounding learned organization and timing standards are independent of the randomized source features.

Use two independently prepared copies of the positive XX source (6). Until their declared collection cuts, their Hamiltonians remain fixed. At the far receiving endpoint of chain i ,

$$\rho_x(q_i) = (1 - xq_i)|0\rangle\langle 0| + xq_i|1\rangle\langle 1|, \quad q_i = \sin^{2N_i-2}(\Omega_i t_i/2).$$

This far-port sine profile differs from the original endpoint's return cosine profile. The same solved amplitudes derive both. The source events and collection delays are chosen so that the first record is collected before the second; calibrated slots identify provenance without disclosing values.

A ready local memory M collects the first endpoint by SWAP; a ready live register L collects the second. At each calibrated collection cut, the endpoint is first decoupled from its source chain. Both the endpoint and collecting register are protected from other dynamics during the finite SWAP pulse. The remaining source stays isolated afterward, so neither an old port, preparation controller nor remote environment supplies an uncounted later carrier. The collection schedule, switches, ready stock and timing reference are counted. A finite SWAP is available over duration $\tau_g > 0$: for a Hermitian involution U , the positive Hamiltonian $H_U = \pi(I - U)/(2\tau_g)$ enacts U . Isolation, switching and pulse durations count toward the use deadline, and all exposure to active memory dynamics counts in the retention interval. The ideal formulas describe isolated protected ports; switching transients and residual chain coupling enter the joint-state calibration budget below. This

composite program is scheduled, not an assertion that the entire observer is autonomous under the original single static Hamiltonian.

Retain M by a specified interaction with one ready inaccessible bath qubit K :

$$H_{\text{mem}} = \frac{\kappa}{2}(X_M X_K + Y_M Y_K) + 2\kappa(n_M + n_K), \quad r = \cos^2(\kappa\Delta).$$

For $\kappa > 0$, its eigenvalues are $0, \kappa, 3\kappa, 4\kappa$; it is positive with a unique ready ground. Tracing K gives the displayed survival after active memory duration Δ . The bath coupling is off during collection and interpretive gates, and on only during the designated retention interval. Count all active-coupling time in Δ and all collection and protection overhead in the use schedule. The controller isolates the bath before the finite interpretive gate; no bath return is allowed before the target. This is reversible physical retention loss, not a stipulated contraction law.

At the local input occasion the complete admitted code is therefore

$$\rho_{ab}^{ML} = \rho_a(p) \otimes \rho_b(q), \quad p = q_A r, \quad q = q_B. \quad (13)$$

Its factorization follows within the ideal program from independent sources and bath, source-isolating collection and absence of cross-route/controller leakage, not merely from fitting separate marginal populations. The decoder may be any common quantum instrument on this code and fresh ancillas in a fixed tensor-product state: $\rho_{ab}^{MLC} = \rho_{ab}^{ML} \otimes \sigma^C$. A merely source-independent ancillary marginal is insufficient. A source-correlated archive, incoming carrier, reference feedback or predictive context changes the declared resources.

6.2 The exact joint-access constraint

A weaker-premise formulation exposes the joint distinction required by the task. Suppose the *joint* record is diagonal in the M, L basis, with pointwise marginals

$$\Pr(M = 1 \mid a, b) = ap, \quad \Pr(L = 1 \mid a, b) = bq.$$

Define the co-retention distinction $j = \Pr(M = L = 1 \mid a = b = 1)$.

Theorem 6.1 (Joint record frontier for directed interpretation). *For independent uniform a, b and the stated complete classical record,*

$$\max(0, p + q - 1) \leq j \leq \min(p, q).$$

Over all common quantum decoders on the counted code, with only fresh fixed-factor ancillary resources, the exact optimal successes are

$$S_D^{\max} = \frac{1+j}{2}, \quad S_{\text{pair}}^{\max} = \frac{1+p+q+j}{4}. \quad (14)$$

Every feasible j is attainable in this classical-record class. For the prescribed independent source (13),

$$j = pq = q_A r q_B, \quad S_D^{\max} = \frac{1 + q_A r q_B}{2}, \quad S_{\text{pair}}^{\max} = \frac{(1+p)(1+q)}{4}. \quad (15)$$

Proof. The pointwise marginals and joint diagonality force this conditional table:

$ab \backslash ML$	00	01	10	11
00	1	0	0	0
01	$1 - q$	q	0	0
10	$1 - p$	0	p	0
11	$1 - p - q + j$	$q - j$	$p - j$	j

Nonnegativity gives exactly the stated interval. A POVM's success on these diagonal states depends only on its diagonal entries; they define an ordinary stochastic decoder. Hence a maximum-a-posteriori deterministic decoder is optimal even among quantum procedures.

For observed 00, multiply the three unnormalized posterior masses by four. They are $2 - p - q + j$ for $D = 0$, $1 - q$ for $D = +1$ and $1 - p$ for $D = -1$; the zero mass is maximal. At 01, $q \geq q - j$ favors $+1$; at 10, $p \geq p - j$ favors -1 ; at 11, only zero occurs. Thus $D_{\text{out}} = L - M$ is optimal, and summing the four maximal masses gives $(1 + j)/2$. For the full pair, guessing the observed pair is optimal; its four correct masses sum to $1 + q + p + j$.

For attainment, choose input-independent joint survival flags (E_A, E_B) with probabilities $j, p - j, q - j, 1 - p - q + j$, and set $(M, L) = (aE_A, bE_B)$. This realizes every feasible table. It proves class sharpness, not arbitrary-source attainability. The independent physical program has $j = pq$, yielding (15). $\square$

Decision-theoretic meaning. The posterior-maximization formula

$$S_f(P) = \sum_y \max_d \sum_{x:f(x)=d} \pi(x)P(y | x)$$

is standard finite Bayesian decision theory. The theorem specializes it exactly to this commuting four-preparation family [1, 3]. The four-flag coupling interval is also established; for example Harrison and colleagues use exactly this Bernoulli coupling bound for correlated packet erasures [9]. Their erasures are visibly flagged, whereas the present basis-input records reset a lost one to zero, an unflagged Z-channel. Functional compression and distributed function computation provide the broader setting [7, 53]. Here the closed task values identify which jointly retained distinction supports a particular temporal operation and connect that requirement to a specified physical delivery/retention program.

Increasing j improves these two uniform-prior target values, but does not order all tasks by informativeness. At $p = q = 1/2$, the $j = 0$ experiment perfectly discriminates preparations 00 and 11, whereas $j = 1/2$ permits only 3/4 success for that binary task, reversing the directed-change ranking. A putative garbling between these experiments must fix outcomes 00, 01, 10 because their preparation rows agree. It then cannot transform either 11 row to the other. The experiments are thus incomparable by a common garbling; no general Blackwell dominance is claimed.

The exact inference concerns an operational target. Reliable directed interpretation with error at most $\epsilon < 1/2$ requires $j \geq 1 - 2\epsilon$. In the prescribed source this means

$$q_A r_{qB} \geq 1 - 2\epsilon, \quad \Delta \leq \kappa^{-1} \arccos \sqrt{\frac{1 - 2\epsilon}{q_A q_B}}, \quad (16)$$

on $0 \leq \kappa\Delta \leq \pi/2$, provided $q_A q_B \geq 1 - 2\epsilon$. Otherwise even perfect retention cannot meet the target. Source delivery or predecessor retention failure now has a specified consequence for this interpretation. It does not imply absence of experience: uncertainty, fusion, an erroneous order or anticipation can still be taken up.

6.3 Countermodels identify the operative premises

Separate marginal calibrations do not determine j . At $p = q = 1/2$, an input-independent shared coin retaining both features with probability $1/2$ and resetting both otherwise gives $j = 1/2$ and

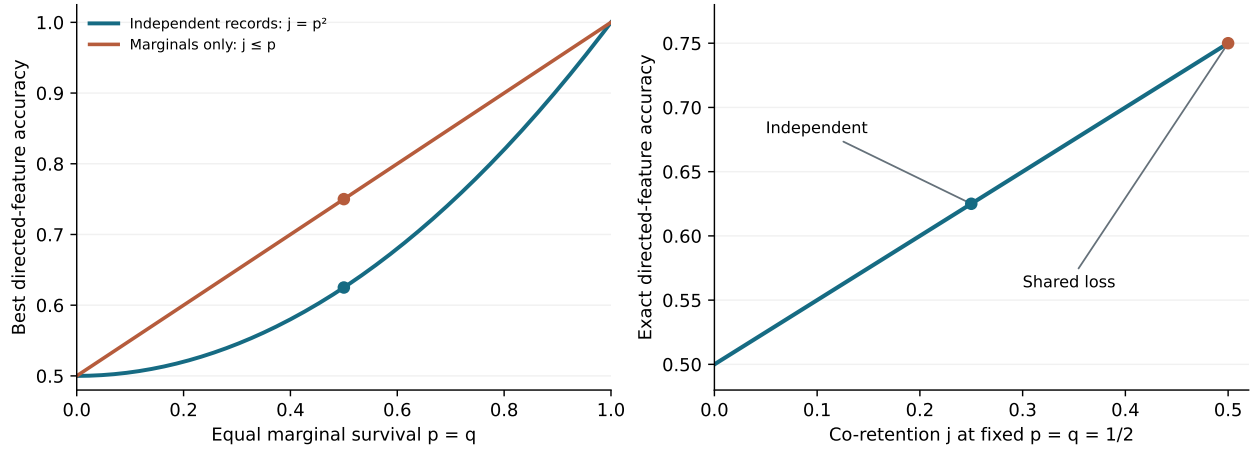


Figure 2: Joint access changes the attainable directed-feature accuracy. Left: equal local survivals yield different product and marginal-only envelopes. Right: at fixed $p = q = 1/2$, the omitted joint distinction j changes the exact optimum from $1/2$ to $3/4$. These are analytic model curves, not fitted observations.

$S_D = 3/4$. The product-source prediction is instead $5/8$. With marginals alone the sharp upper bound is $[1 + \min(p, q)]/2$. Joint access reveals a physically consequential distinction omitted by the marginal description.

For preparation $a = b = 1$, the independent and shared-flag joint laws are

$$(1/4, 1/4, 1/4, 1/4), \quad (1/2, 0, 0, 1/2).$$

Their TV distance is $1/2$, so the equal-prior optimal one-shot identification error is $1/4$. For n independent repeated trials with fresh flags it is exactly 2^{-n-1} . To see this, the only overlapping transcripts have all outcomes diagonal. There are 2^n of them; each has probability 4^{-n} under the product model and 2^{-n} under the shared model. The equal-prior Bayes error is half their overlap sum, namely 2^{-n-1} . The optimal rule selects the product model after any off-diagonal outcome and the shared model otherwise. Its conditional errors are 2^{-n} and zero. Thus finite n never gives perfect identification: an all-diagonal transcript only favors the shared source. Correlated or reused flags across trials require a different transcript law. This protocol uses additional joint access and preserves the complete-law surrogate ceiling. The restricted experiments retain one port per fresh trial, without paired transcripts or cross-port feedback. The hypotheses are equivalent for those separate-marginal experiments and differ for pooled records.

Joint diagonality is also essential. Keep the same local marginals at $p = q = 1/2$, set $\rho_{00} = |00\rangle\langle 00|$, $\rho_{01} = (|00\rangle\langle 00| + |01\rangle\langle 01|)/2$, $\rho_{10} = (|00\rangle\langle 00| + |10\rangle\langle 10|)/2$, but take $\rho_{11} = |\Psi^+\rangle\langle \Psi^+|$. Then $j = 0$, yet a POVM assigning zero to $\text{span}\{00, 11, \Psi^+\}$ and $+1$ to Ψ^- attains $9/16 > 1/2$. Diagonal marginals do not license a classical joint-record theorem. The prescribed independent construction does supply the required joint state.

Likewise, granting a hidden preparation archive defeats any local-code bound. Restricting the ensemble to nonrepeated pairs lets a perfect predecessor identify the pair before the live input arrives. These are changed premises, not stronger interpretations of the same task.

6.4 The complete decoder input and side resources

An auxiliary R can be uniform under every preparation and still improve decoding through its correlations with ML . At $p = q = 1/2, j = 1/4$, extend the product record by this complete diagonal law:

ab	(ML, R) and conditional probabilities
00	$(00, 0) : 1/2; (00, 1) : 1/2$
01	$(01, 0) : 1/2; (00, 1) : 1/2$
10	$(10, 0) : 1/2; (00, 1) : 1/2$
11	$(00, 0) : 1/4; (10, 0) : 1/4; (01, 1) : 1/4; (11, 1) : 1/4.$

For every ab , R is unbiased; tracing it out gives exactly the product ML table. Nevertheless posterior maximization on MLR gives $S_D = 11/16$ and $S_{\text{pair}} = 5/8$, exceeding ML 's $5/8$ and $9/16$. In outcome order $(00, 0), (00, 1), (01, 0), (01, 1), (10, 0), (10, 1), (11, 0), (11, 1)$, the maximal unnormalized target masses for D are $(3/4, 1/2, 1/2, 1/4, 1/2, 0, 0, 1/4)$; those for the pair are $(1/2, 1/2, 1/2, 1/4, 1/2, 0, 0, 1/4)$. Summing and multiplying by the source prior $1/4$ proves the two optima. Marginal source independence is therefore not a sufficient resource certificate. Timing/control metadata require the same scrutiny.

This counterexample is *not* ordinary disclosure of the input-independent survival flags used in the attainment proof. Conditional on each such flag pattern, missing source bits remain uniform, $L - M$ remains MAP for D , and guessing zero for missing bits remains MAP for the pair. Averaging gives the same two optima. Revealing those particular flags does not improve these uniform tasks, although the complete-resource issue remains essential for more general auxiliaries.

Proposition 6.2 (Sufficient certificate for harmless side resources). *Suppose the entire available decoder input is $\sigma_{ab} = \mathcal{C}(\rho_{ab}^{ML})$ for one common CPTP map $\mathcal{C}$. Its optimal task success cannot exceed Theorem 6.1's value. Equality and the original attainer are assured if a common recovery recovers ρ_{ab}^{ML} from σ_{ab} . Fresh fixed-factor ancillas satisfy both conditions.*

Proof. Composing any admissible decoder with $\mathcal{C}$ yields a decoder on the original code, proving the upper bound. With a common recovery, every original decoder can also be executed from σ , proving the opposite inequality. Appending and tracing out a fixed ancillary state supply these maps in the fresh-factor case. $\square$

The certificate is a direct data-processing consequence. For classical extra records it is enough that their conditional distribution given ML be the same under all source preparations. That weaker certificate permits harmless correlations with ML and does not require every controller to be a fresh factor. The auxiliary counterexample fails it.

What the physical construction does and does not supply. The product-state calculation supplies the theorem's premises *conditional on* the scheduled preparation, isolation and control interfaces. Positivity of the source Hamiltonian does not certify those interfaces in an engineered apparatus. A retained label archive can be used for later scoring only if it cannot feed the target decoder before decision. Random feature preparation, timing references and switches must not introduce an accessible correlated completion. Conditional joint-state calibration must include every accessible controller/reference, or establish the preceding certificate for it. No uncharged postselection or later lookup is permitted.

All active memory-coupling time is charged to Δ ; after the bath is isolated, protected storage during the finite native gate is a separate counted resource. If the final decision has a deadline,

collection, isolation, gate latency and readout must fit it too. The finite gate has norm π/τ_g , a control-strength resource not bounded by a bound on the chain couplings alone. The nearest-neighbor spin model is not an exact relativistic speed-limit theorem. These qualifications preserve its status as a physically specified conditional program without claiming an experimental apparatus or autonomous clock has been built.

6.5 Robustness, binding and actual uptake

For actual complete conditional inputs $\tilde{\rho}_{ab}$, append any ideal fresh ancillary factor and write $\rho_{ab}^{\text{ideal}} = \rho_{ab}^{ML} \otimes \sigma^C$. Let

$$\bar{\eta} = \frac{1}{4} \sum_{a,b} D(\tilde{\rho}_{ab}, \rho_{ab}^{\text{ideal}})$$

bound their average trace distance from the complete declared joint decoder input, including accessible side resources (with ideal fresh factors appended where appropriate). Actual states can be coherent or correlated. Each correct-answer effect is between zero and identity, so its probability differs by at most the corresponding trace distance. Taking suprema gives

$$\tilde{S}_D^{\max} \leq (1 + j)/2 + \bar{\eta}. \quad (17)$$

A valid independent confidence lower bound L on success therefore requires $j \geq [2L - 1 - 2\bar{\eta}]_+$. Compatible channel, preparation and finite-gate errors can be added by contractivity and triangle inequalities. Marginal error bars alone do not establish this joint-state premise. All numerical examples here are constructed, not fitted human data.

A finite native update uses ready registers for D , G and a valid-operation flag:

$$(M, L, 0_D, 0_G, 0_{\text{valid}}) \mapsto (M, L, \text{code}(L - M), \text{code}(2L - M), 1).$$

Input-controlled bit flips, including two-input controls (Toffoli gates where necessary), implement it reversibly over finite durations. CNOT gates alone are not asserted sufficient for an arbitrary chosen output encoding. The resulting XOR-on-output map is an involution and also admits the finite Hamiltonian construction above. The G code can feed a fixed downstream comparison or anticipation rule. Its extrapolation is current organization, not reception of an actual future contribution.

Closing the use gate preserves the available archive but leaves the operation flag false and produces no directed update. Swapping actual predecessor/live bindings preserves both records and total information but changes the executed relation to $M - L$. Its actual task success in the product model is $(2 - p - q + 2pq)/4$, instead of $(1 + pq)/2$. A different decoder can correct that swap; the contrast concerns realized use, not a lower resource-class optimum. At ideal delivery, replacing the ordered code by an unordered feature bag permits only $3/4$ success for this directed target. Later addressed retrieval is another operation. Later deletion after an executed update removes later access without undoing the earlier event.

For a human application, a distinct realization premise must establish that these delivered relations actually enter the already qualifying person's grounded ongoing uptake. The finite device does not establish the person's complete qualification or experiential boundary. Under the selected complete-enactment constitution, an actually integrated predecessor/live/anticipatory relation belongs to the experience itself; no later experiential output or moving present converts it. A third source event may occur only after this update, so the earlier transition can already be enacted before the sequence finishes.

The result is a source-to-functional-interpretation constraint with a conditional experiential application. A successful classical order task does not certify quantum completion. The reference-assisted readiness theorem requires separate incompatible preparations and tests with its own inert-reference and closed-cut assumptions. Ordinary environmental records and embedded-observer accounts survive both arguments; the source-linked joint-access, timing, intervention and calibration constraints identify precisely what the nominated temporal operation needs.

7 What kind of completion must a coherent return retain?

Binary information can return through an ordinary classical archive. Coherent return asks more: can the omitted completion preserve noncommuting quantum distinctions? This question makes the source-readout argument discriminate between resource classes instead of inferring a rich source by definition.

At the prescribed chain's ready cut, prepare R, S initially in $|\Phi_d\rangle = d^{-1/2} \sum_{j=0}^{d-1} |j, j\rangle$, using parallel chains for $d = 2^n$. In trace-distance expressions Φ_d denotes its density operator. Keep R inert and inaccessible to the recovery apparatus. A final joint measurement is allowed only after the output has been formed; it supplies no earlier signal from R .

An S -only update at the exact ready cut produces $I_R/d \otimes \sigma_S$. Its Bell probability is $1/d^2$, independent of σ . Hence

$$\inf_{\sigma} D(\Phi_d, I_R/d \otimes \sigma) = 1 - \frac{1}{d^2}. \quad (18)$$

The Bell event gives the lower bound; choosing $\sigma = I/d$ attains it by direct eigenvalues. For a qubit this is $3/4$, rather than the binary target's $1/2$. These are different operational targets.

7.1 A sharp readiness/completion frontier

We now quantify approximate readiness. Both R and the nominated subsystem S have dimension d . At a causal cut, every later accessible carrier besides S is counted as C, Q : C is genuinely classical, meaning the joint state is block diagonal in one fixed C basis; Q has dimension $1 \leq k \leq d$. All later processing is a common unconditional CPTP map on S, C, Q and fresh ancillary states initially in a fixed tensor-product factor with the complete cut input. There is no access to R , additional R -correlated input or uncounted coherent reference memory. Let

$$\Pr(S = 0) = \text{Tr}(P_0 \rho) \geq 1 - \epsilon, \quad f = \langle \Phi_d | \rho_{RS}^{\text{out}} | \Phi_d \rangle, \quad P_0 = |0\rangle\langle 0|_S \otimes I.$$

This readiness condition is a local probability that can be independently calibrated. It is not merely absence of correlation in a reduced marginal.

Theorem 7.1 (Quantum completion across a nearly ready cut). *In the stated resource class the largest possible Bell probability is*

$$B_{k,d}(\epsilon) = \begin{cases} \left(\sqrt{\frac{k}{d}(1-\epsilon)} + \sqrt{\left(1 - \frac{k}{d}\right)\epsilon} \right)^2, & 0 \leq \epsilon \leq 1 - k/d, \\ 1, & 1 - k/d \leq \epsilon \leq 1. \end{cases} \quad (19)$$

The bound is sharp, including for a maximally mixed reference marginal, over freely chosen pre-cut instruments and post-cut decoders in this class. This sharpness is a resource benchmark, not an attainment guarantee for an arbitrary prescribed source.

Proof. First take exact readiness. The state factors as $|0\rangle\langle 0|_S \otimes \rho_{RCQ}$. In each classical C branch, R, Q has a decomposition into pure states of Schmidt rank at most k , because $\dim Q = k$. Local CPTP maps, ready ancillas and forgetting classical flags cannot increase that bound: apply each local Kraus operator to each pure branch. For any Schmidt bases, a normalized rank- k vector obeys $|\langle \Phi_d | v \rangle| \leq d^{-1/2} \sum_j \sqrt{\lambda_j}$, and $(\sum_j \sqrt{\lambda_j})^2 \leq k$ by Cauchy–Schwarz. Its Bell overlap is therefore at most k/d . Convexity extends the bound to mixed outputs. This is the established Schmidt-number witness [18, 48], here applied to a counted causal completion.

For approximate readiness purify the complete cut state as $|\psi\rangle$, and set $p = \langle \psi | P_0 | \psi \rangle$. If $p > 0$, its normalized projection $|\phi\rangle = P_0 |\psi\rangle / \sqrt{p}$ has $\langle \phi | \psi \rangle = \sqrt{p}$ and produces Bell probability $f_0 \leq a := k/d$ after the same channel. Represent the channel by an isometry and the Bell test by a projector M on the extended output. Cauchy–Schwarz on M and $I - M$ gives

$$\sqrt{p} \leq \sqrt{f f_0} + \sqrt{(1-f)(1-f_0)}.$$

Writing $\theta = \arccos \sqrt{f}$, $\theta_0 = \arccos \sqrt{f_0}$ shows $|\theta - \theta_0| \leq \arcsin \sqrt{\epsilon}$. Since $\theta_0 \geq \arccos \sqrt{a}$, for $\epsilon \leq 1 - a$ we obtain $f \leq \cos^2(\arccos \sqrt{a} - \arcsin \sqrt{\epsilon})$, which is (19). Outside that range use $f \leq 1$. Zero-probability projection and $k = d$ are trivial cases.

For sharpness suppose $k < d$, let $m = \binom{d}{k}$, and label C by all k -subsets A of the computational basis. Choose an isometry $V_A : \mathbb{C}^d \rightarrow S \otimes Q$ that sends the basis vectors in A into $|0\rangle_S \otimes Q$ and all others into its orthogonal complement. Such an isometry exists because $\dim(S \otimes Q) = dk \geq d$. Let D_A be diagonal with entries $\sqrt{(1-\epsilon)/k}$ on A and $\sqrt{\epsilon/(d-k)}$ elsewhere, and define

$$K_A = \sqrt{d/m} V_A D_A.$$

Each basis vector lies in a fraction k/d of the subsets, so $\sum_A K_A^* K_A = I$. These are a valid pre-cut instrument, with outcome A retained classically. On half of Φ_d , every branch has probability $1/m$, readiness $1 - \epsilon$, and Schmidt weights $(1 - \epsilon)/k$ on A and $\epsilon/(d - k)$ elsewhere. Decode with V_A^* on its image, extended to a trace-preserving channel on unused dimensions. Every branch then has Bell probability $[\sqrt{k(1-\epsilon)} + \sqrt{(d-k)\epsilon}]^2/d$. The reference remains maximally mixed because the total pre-cut instrument is trace preserving. For larger ϵ , use $\epsilon' = 1 - k/d$ to attain one while satisfying the readiness inequality. For $k = d$, store the full input in Q with S ready. This proves sharpness. $\square$

For a qubit with only classical completion ($k = 1, d = 2$),

$$f \leq \frac{1}{2} + \sqrt{\epsilon(1-\epsilon)} \quad (0 \leq \epsilon \leq 1/2). \quad (20)$$

At $\epsilon = 0$ this is the familiar entanglement-breaking benchmark $1/2$ [11]. The robust form states exactly how a small amount of quantum information left in S can weaken an inference about memory *outside* S . For instance readiness 0.99 permits classical-completion Bell probability at most 0.59950, not arbitrarily close to one. A useful simpler consequence is $f \leq k/d + \sqrt{\epsilon}$ and therefore $k \geq \lceil d(f - \sqrt{\epsilon}) \rceil$ when the right side is positive. Use independently justified confidence bounds and calibration margins, not point estimates alone. Postselected successful runs require charging acceptance probability; the theorem concerns unconditional outputs.

The frontier combines established Schmidt-number and purity constraints. In the qubit case its envelope also follows from singlet-fraction, negativity and marginal-purity inequalities [50, 51]. The causal-cut formulation specifies their physical significance: sufficiently reliable coherent return requires enough coherent completion across the cut, rather than merely an archive of classical answers.

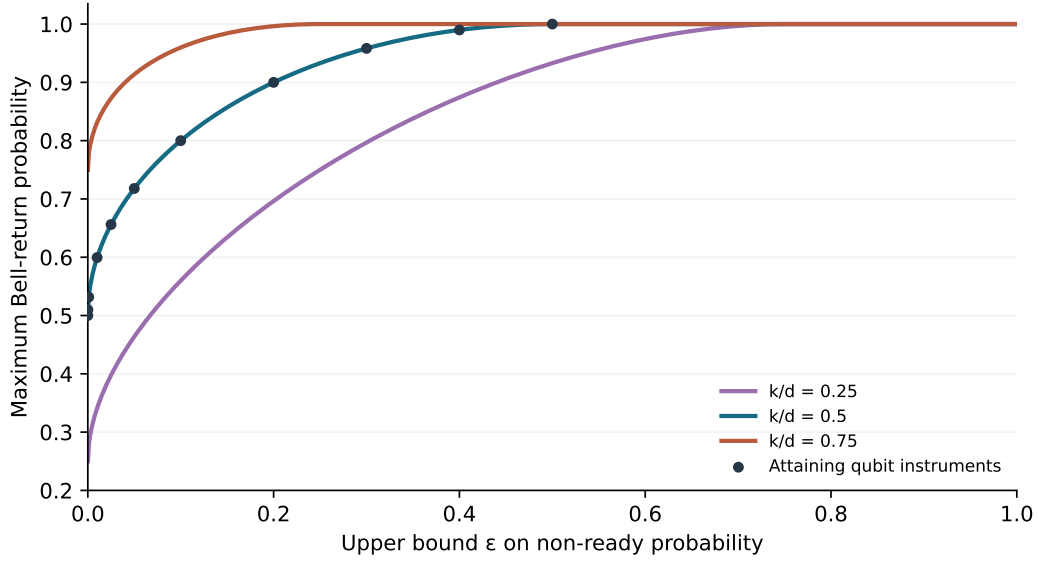


Figure 3: Exact permitted Bell return versus departure from a pure ready state. The ratio k/d counts coherent dimensions outside the nominated subsystem; arbitrary classical flags are allowed. Points check explicit attaining qubit instruments. This is a resource-class frontier, not a fit to experimental data.

7.2 Why reduced-state equality is insufficient

An essential countermodel uses a quantum one-time pad [16]. Apply one of I, X, Y, Z to half of a Bell pair, retain the uniformly sampled key in classical C , and omit it from the reduced description. The resulting RS marginal is $I/4$, and $S = I/2$ carries no marginal input dependence. Reading the key and undoing the Pauli returns the Bell state perfectly. No outside quantum register is needed in this operational model; coherent information remains in S together with its classical key correlations. This does not contradict no-hiding for a fully purified unitary environment. It shows why a product RS marginal alone cannot locate the required quantum resource outside S . The pure-ready premise, or its quantified robust replacement, does real work.

7.3 A discriminating protocol and its exact reach

Prepare a reference-entangled input and the calibrated ready chain. On separate, identically prepared runs estimate midpoint readiness, then test return fidelity without accessing R before the output is formed. Preserve all outcomes. Compare the independently bounded f with (19). At the ideal T cut, the actual chain returns $f = 1$, while an endpoint-only account gives Bell probability $1/4$ and any purely classical closed completion gives at most $1/2$. Thus, within quantum operational physics, the protocol requires a coherent completion outside the ready endpoint.

A local replacement of the already ready endpoint at T leaves the ideal global state unchanged; replacing or decoupling the remote carrying spin can instead remove the return. These are distinct interventions on the specified causal route, not additions to the unperturbed Hamiltonian proof. They can locate the relevant memory mechanism if implemented and calibrated. These are proposed interventions, not reported experimental results.

Ordinary quantum environmental memory supplies exactly the successful completion. A complete

process tensor also supplies the correct multitime laws [19]. The test excludes the declared restricted repair, not all mathematical classical ontologies or all operational surrogates. Its discriminating content is source-specific: loss, timing, recovery, approximate readiness and the required coherent resource follow from the same program and can be compared with observable tests.

8 Occasions, calibration and continuing temporal use

The source-linked bound concerns an available code and a declared operation. Temporal interpretation also needs an executable schedule, grounded source references and actual use. These requirements constrain different stages; none follows merely from storing a correct pair of symbols.

8.1 A finite opportunity for joint use

Let a_1, a_2 be arrivals measured on one observer's local clock. A trace from the earlier arrival survives through age M , and consolidating the pair into the specified operative relation needs latency $\lambda > 0$ after the later arrival. A possible uptake occasion v must satisfy

$$\max(a_1, a_2) + \lambda \leq v \leq \min(a_1, a_2) + M.$$

Consequently

$$|a_2 - a_1| + \lambda \leq M \tag{21}$$

is necessary. Under the component model with guaranteed trace access through M and an executable update of latency λ , it is sufficient for that *schedule*: choose its lower endpoint. It is not sufficient for a qualified human experience. If both traces decay, their individual age constraints must both hold. If memory is probabilistic rather than a hard window, the survival r in the preceding theorem replaces this all-or-nothing component guarantee.

An illustrative RC component has $r_V(\Delta) = V_0 e^{-\Delta/(RC)}$ and a detectable lifetime $M = RC \log(V_0/V_{th})$ [36]. For the illustrative values $R = 250 \text{ k}\Omega$, $C = 1 \mu\text{F}$, $V_0 = 1 \text{ V}$, $V_{th} = 0.4 \text{ V}$, $M = 0.229073 \text{ s}$. This voltage is not the quantum probability $r = \cos^2(\kappa\Delta)$: they are distinct physical retention models. A finite trace and threshold support one timing component; neither a classical capacitor nor an order detector automatically satisfies a quantum coherent-completion theorem. Component construction has established electronic precedents [39]; a complete embodied interpreter is an additional realization obligation.

8.2 Calibrated source order and its uncertainty

For two timelike source onsets with gap Δ_s , delivery delays δ_1, δ_2 give $\Delta_a = \Delta_s + \delta_2 - \delta_1$. The local interpreter can use received arrival times and learned estimates $\hat{\delta}_i$ to form

$$\hat{\Delta}_s = \Delta_a - \hat{\delta}_2 + \hat{\delta}_1.$$

It is not given the actual source timestamps as a free oracle. If $|\hat{\delta}_i - \delta_i| \leq \eta_i$, then

$$|\hat{\Delta}_s - \Delta_s| \leq \eta_1 + \eta_2. \tag{22}$$

For a full rectangular set of bounded delay errors, the sign is guaranteed exactly when $|\hat{\Delta}_s| > \eta_1 + \eta_2$. Within that band, allowed errors can make zero or a contrary sign consistent. A finite coincidence

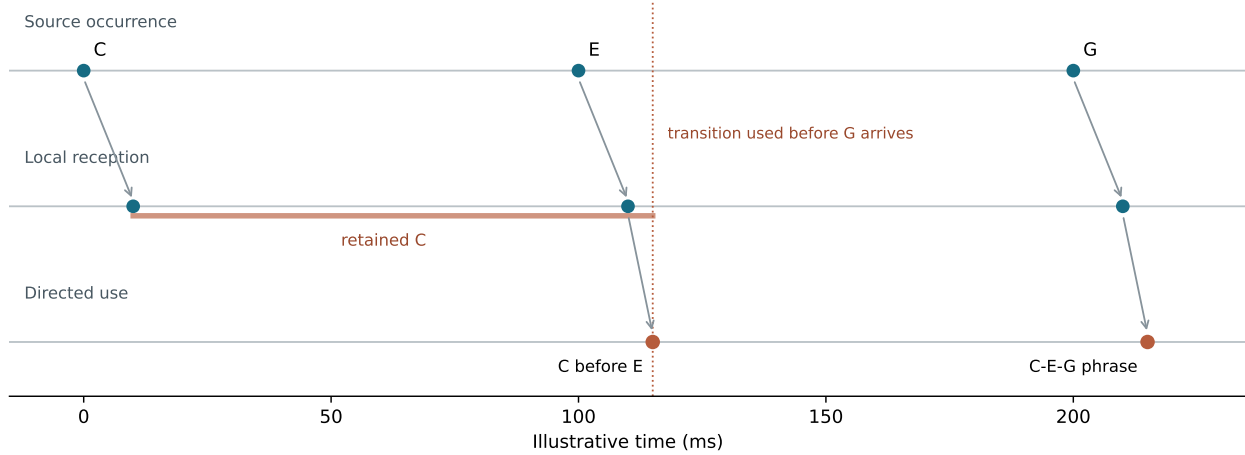


Figure 4: A constructed local schedule distinguishes source occurrence, reception and directed use. The retained C contribution and live E contribution enter a transition before G arrives. The vertical line marks one local occasion, not a universal present. Common availability preserves distinct represented temporal roles.

band should therefore produce an unresolved relation, not an order assigned by arbitrary event identifiers. The directed-feature theorem assumes fixed earlier/live provenance; this calibration problem is a separate requirement for assigning that provenance in an actual apparatus.

A calibrated-delivery example sends C at 0 ms with 80 ms delay and E at 50 ms with 10 ms delay. Arrival order is E, C , while correctly calibrated source order is C, E . Learned recalibration of judged order has empirical precedents [45]. It does not reverse a physical cause, change proper time, or supply an absolute ordering of spacelike events.

8.3 Continuing uptake without waiting for a finished sequence

In the constructed melody, source onsets C, E, G occur at 0, 100, 200 ms. Reception delay 10 ms and integration delay 5 ms make a $C-E$ relation operatively available at 115 ms, before reception of G at 210 ms. A continuing activity can then incorporate G at 215 ms. These chosen values demonstrate a schedule, not a measured universal human integration window.

The operative state distinguishes source references, feature values, stream binding, represented order, live/retained/retrieved/anticipated mode, delay calibration and actual use. A retained predecessor and live contribution can therefore participate together without being represented as simultaneous. Anticipation is a current organization concerning a possible continuation. In an illustrative continuation model the same $C-E$ prefix supports learned probabilities 0.75 for G and 0.25 for D . Different later environments preserve that prefix; the corresponding later surprises are 0.287682 and 1.386294 nats. An omission changes the expectation state without becoming a received note. These probabilities and deadlines are stipulated model parameters.

Neither a correct truth table nor a flag named U establishes interpretive uptake in a person. The finite transducer's open-use condition means the directed relation actually drives its declared continuation or action update; closing that route leaves an archive without this operative effect. To apply the experiential identity, the contribution must enter the already qualifying person's grounded recognition, relating or response organization, with all other constitutive conditions

intact. Correctness from a separate later lookup cannot establish that earlier use. This is an empirical application condition, not an extra event converting an otherwise complete enactment into experience.

8.4 What the empirical comparisons constrain

Auditory fusion makes the distinction consequential: sequential nonoverlapping tones can be reported as one synthetic vowel, so retained identities and temporal overlap alone do not specify experienced succession [40]. Pitch, signed pitch change and contextual expectation also have differentiable neural encoding profiles [41]. Omission responses support predictive organization beyond the received acoustic prefix [52]. A single severely amnesic patient’s narrative-sensitive activity supports separating ongoing integration from durable recall [54]. These findings constrain different components; none alone establishes actual grounded uptake in a particular person, a universal developmental requirement, or the complete experiential identity.

These findings have distinct evidential scopes and dependencies. Stetson’s behavioral and imaging samples overlap, including repeated participants across hand conditions. Zuo’s healthy controls reuse an earlier dataset. Sankaran’s main recordings involve eight patients, not one independent participant per electrode; its preprint and publication are one work. These dependencies limit claims of independent convergence. The studies support specific mechanism claims, while the constitutive interpretation requires its own argument.

8.5 Proper time, duration judgments and felt pace

An interval along a worldline, record asymmetry, a duration response and felt pace are distinct targets. A partial pace model separates these targets without claiming a complete law of phenomenal character [36]:

$$D_\tau = \alpha B + \beta N, \quad J_\tau = \kappa_p \log \frac{N/B}{\rho_0} + \eta \log \frac{E}{B}.$$

B is an internal elapsed estimate, N the number of interpreted event boundaries, and E an expected endpoint; ρ_0 sets a learned reference rate. At fixed B , the Jacobian with respect to $(N, \log E)$ has determinant $\beta\eta$. Its nonzero value for chosen parameters is a property of the model, not evidence that human responses have measured rank two. Density and endpoint-expectation studies motivate distinct contrasts, but do not fit this equation [15, 46]. Within these studies, partly shared participants and reused comparison conditions prevent treating each analysis as an independent replication.

Common proper-time scaling alone cannot explain a change in the ratio between a local timing process and a local watch: if both scale with proper time, their ratio is unchanged. Relativistic clock differences and changes in judged duration or felt pace are therefore distinct explanatory targets. The equations above are constructed models, not fits to participant data; a timing task must be identified before a change in its response is interpreted as a change in felt passage.

9 Does the integration require a source beyond physical history?

9.1 The obstruction must be located on the correct map

The source–readout claim has different possible strengths. A specified model may contain a restricted physical presentation. Independently calibrated observations can then require distinctions beyond a nominated description. A further conclusion would identify physical reality itself as a readout of a particular richer source. The source-to-use construction establishes the first kind of result and supplies a conditional route to the second. The third requires a separate argument.

Proposition 9.1 (Composition and the identity countermodel). *Let $F : \mathcal{S} \rightarrow \mathcal{H}$ be onto, $q : \mathcal{H} \rightarrow Z$ a record map and $f : \mathcal{H} \rightarrow A$ a target. If $q(h_0) = q(h_1)$ but $f(h_0) \neq f(h_1)$, then f does not descend through q , and $f \circ F$ does not descend through $q \circ F$. This implies neither noninjectivity of F nor the need for a source beyond $\mathcal{H}$.*

Proof. A function of the same record must give the same target value, contradicting the stipulated pair. Surjectivity supplies source antecedents and lifts this obstruction. For the non-entailment, set $\mathcal{S} = \mathcal{H}$ and $F = \text{id}$. The local obstruction remains while the history map is injective. $\square$

For example, $\mathcal{H} = \{0, 1\}^2$, $q(a, b) = a$, $f(a, b) = b$ already realizes the countermodel. The full history can be a perfectly adequate working source for the local record. Adding a silent coordinate to $\mathcal{S}$ creates a richer representation with the same histories, but its availability as a mathematical construction is not evidence for an additional physical bearer.

This identifies the precise reciprocal gain rather than abandoning the source programme. Relativistic history constrains the access map; target-relative completion identifies what the access map must retain. A physical history can itself be shown to arise from a nominated deeper realization where that model has independent warrant. No inference from q -loss to F -loss is needed or licensed.

9.2 A completed intervention test of passive-history sufficiency

A materially different way to challenge a nominated description is to ask about interventions rather than another passive marginal. Even an entire passive *reduced* trajectory can fail to determine the response to a common control. The distinction matters in a block: one actual trajectory and a model's counterfactual response laws are different explanatory objects.

Take two ordinary qubits E, S , with E prepared in $|\lambda\rangle$, $\lambda \in \{0, 1\}$, and S in $|0\rangle$. During a dwell interval $T > 0$, use the positive Hamiltonian

$$H_{ES} = \frac{\pi}{T} |11\rangle\langle 11|, \quad U_{ES}(T) = |0\rangle\langle 0|_E \otimes I_S + |1\rangle\langle 1|_E \otimes Z_S.$$

The passive reduced trajectory is $\rho_S^\lambda(t) = |0\rangle\langle 0|$ for every t and either preparation, since each initial vector $|\lambda, 0\rangle$ has zero energy. Now apply a Hadamard W to S , dwell for T , and apply W again. Since $WZW = X$ and $W^2 = I$,

$$(I \otimes W)U_{ES}(T)(I \otimes W)|\lambda, 0\rangle = |\lambda, \lambda\rangle.$$

The same final Z measurement therefore distinguishes the preparations perfectly. A predictor supplied only the identical passive reduced trajectory must issue one Bernoulli probability m for outcome one. Its two preparation-conditioned TV errors are m and $1 - m$, so its minimax error is

exactly $1/2$. With final-law calibration errors η_0, η_1 , exact passive equality instead gives the lower bound $[1 - \eta_0 - \eta_1]_+/2$ by the triangle inequality. This applies the established half-TV obstruction [29, 34]; it is not a new universal information inequality.

The preparation archive and E are inaccessible to the target decoder before its decision. Isolate the interaction during the finite control pulses and count their durations, control strength, timing and protected storage. The involution Hamiltonian $\pi(I - W)/(2\tau_g)$ supplies each pulse over $\tau_g > 0$ in the ideal schedule. Its operator norm is π/τ_g ; the total pulse-dwell-pulse duration is $T + 2\tau_g$, with dwell interaction norm π/T . The common schedule is independent of λ . Joint calibration must cover interface and switching errors. No stochastic source seed has been appended. The omitted distinction is an ordinary environment state with an independently specified coupling.

The positive lesson is stronger than insufficiency of one instantaneous density matrix: a complete passive local path still need not determine an active response. A process tensor or an equivalent intervention-sensitive specification supplies the missing response laws; the passive path alone does not [5, 19]. This is an elementary illustration of an established distinction, not a new general process theorem. The limit is equally exact. The *complete physical* histories include E and differ in λ , so $F = \text{id}$ remains available. The construction is an intervention diagnostic and a physical completion, not proof of a nonspatiotemporal source.

9.3 Comparison with the strongest source results

The relevant comparisons concern hypotheses and conclusions, not terminology.

Result	What the assumptions establish	Relation to the present integration
Canonical descent and dynamics [24–26, 28, 29]	Target variation in a nominated fiber requires completion; noninvariant kernels obstruct autonomous projected dynamics.	Supplies the general criteria. Physical delivery/use instantiates them; it does not enlarge them universally.
RS2 witness [30, 42]	Within the admitted bulk class, identical instantaneous brane data can have different later brane readouts.	A gravitational source model, distinct from loss in every complete physical history. Its residues require independent physical testing.
Bell and resource results [34]	Under the exact Bell/source premises, a nominated initial classical readout leaves conditional information unresolved; finite resources constrain access.	Stronger than bare observer ignorance, but no removal of its determinism, independence or no-signalling hypotheses follows from a block.
Global quantum-record result [23]	A source-carried future selector, absent from the preceding Tier-1 filtration and preserved by reduction, supplies maximally different objective-record continuations from one present.	Pathwise nonclosure of the present within a declared source realization; different from noninjectivity of the source-to-entire-history map.

Result	What the assumptions establish	Relation to the present integration
Delivery, joint-code and coherent completion	Calculated couplings and complete resource cuts bound particular future uses.	A source-specific operational constraint and conditional experimental route, with ordinary environmental completion still possible.

The global quantum-record theorem deserves precise treatment. Its regular-branch assumptions include a future selector carried by source/preparation structure, nonmeasurability in the preceding realized Tier-1 filtration, conditional full support, measurement independence and source reduction that preserves distinctions producing different objective records [23]. Those assumptions support the pathwise witness. A nontrivial Born kernel alone establishes a conditional outcome law; representing that law with a uniform randomizer does not independently establish an extra physical substrate. Distributional closure can coexist with failure of a present state to determine a single realized continuation.

Its complete-history result is separate. A lawful nonisomorphic inactive source extension can preserve the complete Tier-1 history law, proving non-identifiability of source architecture in that admitted class. Isomorphic active apertures are a sufficient route to equal laws; equal laws do not, without an additional identifiability theorem, determine an aperture isomorphism class. The physically warranted conclusion is an operational/readout equivalence class. Neither a new silent sector nor the same realization theorem establishes its physical necessity.

9.4 What evidence would make the stronger argument stronger?

Let $\Xi(s) = (\mu_{e,s})_e$ be the family of record laws under all admitted experiments, including adaptive interventions. A nominated description $r(s)$ supports those laws exactly only if

$$r(s) = r(s') \implies \Xi(s) = \Xi(s').$$

This is family-relative descent. Additional access can enlarge Ξ and split a previous equivalence class, as the active and pooled-record protocols do. Yet canonical protocol equivalence and the complete-law surrogate result already allow a history/process model reproducing every law of the enlarged class [30, 34]. Reconstructing causal history kernels is therefore not a new way past that ceiling.

A positive stronger inference needs independently justified restrictions on the alternatives: a closed causal cut, finite coherent memory, locality/factorization, incompatible preparation structure, or a specified dynamical law. The readiness/completion theorem supplies exactly such a conditional inference without assuming source-level outcome determinism. A universal source-beyond-physical-history conclusion would need a reason that every adequate whole-history realization fails a warranted condition, or evidence selecting a particular deeper physical model over its competitors. Neither local temporal experience nor the block interpretation currently supplies that reason.

The substantive outcome is thus an exact advance in realization and explanation, rather than a new universal ontology proof. A source-accurate temporal relation requires physically attainable completion at its use occasion. Its experiential significance follows under an independently defended constitution. The stronger physical-source question remains well specified, and is not answered by confusing these two achievements.

10 The reciprocal contribution and its limits

A complete-history account and Shadow Theory do more together than assert that observers have incomplete information. The relativistic setting supplies causal order, proper-time schedules and a distinction between common existence and common availability. Shadow's target-relative mathematics identifies the exact missing relation, its physical realization determines whether it can reach and survive to the operative occasion, and its enacted proposal supplies a conditional account of the resulting temporal experience. The source-to-use program connects these steps for the same directed relation.

For the block account, the payoff is a constructive answer to a particular explanatory demand. A retained predecessor, live contribution and anticipated continuation can be differently organized within one continuing activity. Their common availability need not represent simultaneity. Uptake can precede the end of the sequence, and later forgetting does not undo its occurrence. Experience without psychological appropriation remains possible within the constitution because bodily indexing, retention and interpretation need not constitute an independent owner. An external projector performs no additional required operation once the complete qualifying activity is admitted.

Removing eternalism leaves the quantitative resource bounds unchanged. Its contribution is the interpretation of global actuality and local differentiation, not an extra experimental confirmation of the bounds. Removing Shadow's completion language leaves the underlying quantum and relativistic mechanisms, while relinquishing the explicit target-fiber/attainability question and the chosen experiential constitution. Their combination is explanatory, without being logically indispensable to every mathematical component.

For Shadow, the payoff is a disciplined physical realization. Source, history, record and interpretation cannot be interchanged. Preparation, communication, joint-state calibration, finite retention, source binding and operative use constrain what the local presentation can support. The exact accuracy frontier and coherent-completion bound make those constraints quantitative. An ordinary environment can carry the omitted distinction; a later completion can be a real causal source for a new readout. This is a structure of reciprocal physical dependence inside the history, not reciprocity of actuality by definition.

The direct reciprocal-pair theorem sharpens a separate ontological branch. Translation, transitivity and the specified boost/spatial symmetries make a single distinct mutual pair decisive without dilation or global symmetry. The same universality conclusion holds under weaker premises than the classification-based route. Its interpretation still requires a defensible fixed actuality relation and a reciprocal witness. Process duration, causal dependence and covariant observer families do not supply them. The block's economy has a precise Shadow contribution: an additional activation selector contributes no required distinction to minimal completion when the declared predictions, records and complete qualifying enactments are unchanged. Experiential equivalence uses the constitutive identity; neither target-relative minimality nor removal of an extra variable proves an exhaustive ontology or removes indexed relations definable from geometry. Relational becoming remains a serious alternative.

The physical readout argument is correspondingly precise. It excludes particular closed descriptions and yields discriminating protocols within warranted resource classes. It does not prove that the source-to-entire-physical-history map must be lossy. The identity realization survives local and passive-history obstructions, and complete operational surrogates survive equal experiment laws. No stronger universal source conclusion is established here than the best existing source theorems under their actual assumptions.

The strongest remaining challenge is independent warrant and application of the experiential constitution, together with an empirical or theoretical premise that genuinely excludes the nominated whole-history alternatives. These are distinct questions. Progress on temporal explanation need not wait for a universal subject selector or a proof of the unknown Ground, but it must not be advertised as either. The resulting integration is substantive and conditional: it explains how a source-supported temporal relation becomes locally operative and, under a stated constitution, experienced within a complete history.

A Direct reciprocal-pair proofs and their exact scope

The proof concerns one relation on real Minkowski events. It assumes neither that the relation is actuality nor that an observer's indexed access relation is invariant with its index held fixed.

A.1 The mutual core is a subgroup

By transitivity of a reciprocal witness, $R(p_0, p_0)$. Translation by $p - p_0$ yields $R(p, p)$ for every p , deriving reflexivity. Define

$$H = \{v : R(0, v) \wedge R(v, 0)\}.$$

Zero belongs to H . Translating the two links for v by $-v$ gives $-v \in H$. If $v, w \in H$, translation gives $R(v, v + w)$ and $R(v + w, v)$; transitivity with the links between zero and v gives both links between zero and $v + w$. Thus H is an additive subgroup. Every assumed linear symmetry preserves it, and translating the original witness gives $q_0 - p_0 \in H \setminus \{0\}$. No general closure of H under real scalar multiplication has been assumed.

A.2 Generation in real 1 + 1 dimensions

For $v = (t, x) \in H \setminus \{0\}$, reflection gives $Pv \in H$. Both

$$v + Pv = (2t, 0), \quad v - Pv = (0, 2x)$$

belong to H , so it contains a nonzero pure-axis vector. For every $s \in \mathbb{R}$ choose

$$\ell = \frac{s + \sqrt{s^2 + 4}}{2} > 0, \quad \ell^{-1} = \frac{\sqrt{s^2 + 4} - s}{2}.$$

Their product is one and $\ell - \ell^{-1} = s$. For a nonzero temporal vector $(a, 0)$, boost differences give

$$B_\ell(a, 0) - B_{1/\ell}(a, 0) = (0, a(\ell - \ell^{-1})).$$

Since $a \neq 0$ and s is arbitrary, every spatial vector belongs to H . Fix $\ell = 2$, with boost coefficients $c = 5/4$ and $b = 3/4$. Boosting $(0, x)$ and subtracting the spatial vector $(0, cx)$ gives $(bx, 0)$, so every temporal vector belongs as well. Starting from a pure spatial vector exchanges these steps: opposite boosts first generate all temporal vectors, then a fixed boost supplies all spatial vectors. Addition gives $H = \mathbb{R}^2$.

For any events p, q , $q - p \in H$, hence $R(0, q - p)$. Translation by p yields $R(p, q)$, proving universality. The algebraic proof also works over an ordered field with positive square roots; the formal direct modules here are specialized to the reals. If the original reciprocal displacement is nonnull, a boost can put it on a pure axis, so reflection is unnecessary for that restricted witness class. For a null-only witness, the null-line countermodel below shows why reflection matters in 1 + 1.

A.3 Generation in real $3 + 1$ dimensions with proper half-turns

Write $v = (t, x_0, x_1, x_2)$ and let H_i be the spatial half-turn fixing axis i and reversing the other two spatial coordinates. Each is a proper rotation with determinant $+1$. Assume translations, transitivity, every positive-parameter boost along each coordinate axis, and these three half-turns preserve R . These linear transformations belong to the proper orthochronous Lorentz group; their invariance suffices together with the separate translation assumption.

The subgroup argument gives a nonzero $v \in H$. If $t \neq 0$,

$$(v + H_0 v) + H_1(v + H_0 v) = (4t, 0, 0, 0) \in H.$$

If $t = 0$, choose i with $x_i \neq 0$. The difference of axis- i boosts with parameters 2 and $1/2$ is

$$B_{i,2}v - B_{i,1/2}v = (3x_i/2, 0, 0, 0) \in H.$$

Thus in either case a nonzero pure temporal vector ae_t belongs to H . Along each axis i the difference

$$B_{i,\ell}(ae_t) - B_{i,1/\ell}(ae_t) = a(\ell - \ell^{-1})e_i$$

generates every spatial vector on that axis. A fixed axis boost of any such vector, followed by subtraction of its spatial component, generates every temporal vector. Finite addition now gives $H = \mathbb{R}^4$. Translation concludes the proof. The half-turns do not invoke global spatial parity, and no dilation or continuity principle was used.

A.4 Countermodels and comparison with classification

Without boosts, $R(p, q) \iff p^0 = q^0$ satisfies the other requirements but is nonuniversal. Without translation invariance, equality of Minkowski norm relative to a selected origin is a Lorentz-invariant nonuniversal equivalence relation with distinct mutual pairs. Without transitivity, $p = q$ or spacelike separation gives a symmetric invariant relation with mutual pairs but not universality; for example the two spacelike displacements $(1, 2)$ and $(1, -2)$ have timelike sum $(2, 0)$. Without a distinct mutual witness, causal-past order is nonuniversal and satisfies transitivity and the stated translation, boost and spatial-transformation invariances; it is not a symmetric relation. In $1+1$, $p^0 - p^1 = q^0 - q^1$ is translation/boost invariant and reciprocal. It is the equivalence relation of a foliation by parallel lines in one null direction and is not reflection invariant.

These statements concern a direct implication, not a six-way classification without dilation. For fixed $L > 0$ in null coordinates, the relation

$$R_L(p, q) \iff p = q \text{ or } u < 0, w < 0, uw \geq L^2, \quad u = \Delta t + \Delta x, w = \Delta t - \Delta x$$

is translation/boost/reflection invariant and transitive. For two nonidentity links write their positive past-coordinate magnitudes as $(a, b), (c, d)$ with $ab, cd \geq L^2$. Their sum has product $(a + c)(b + d) \geq ab + cd \geq 2L^2$, proving transitivity. At fixed L an active dilation can violate the threshold. This relation has no distinct reciprocal pair and therefore leaves the direct theorem intact.

The classification-based reciprocal module uses the stronger invariant structure, including dilation, and eliminates the five nonuniversal cases by their trivial mutual cores. The two direct real modules prove the weaker-premise implications without that classification. All three versions are mathematically consistent but have different dependency sets. The formal statements and axiom audits are provided with the executable supplement; their universality conclusions alone establish no physical actuality premise.

B Formative dependence, admission and the conditional adult application

A local interpretive recipe and a universal historical admission rule are different claims. The experiential-contributor formulation requires a qualifying activity to have an actual formative contribution from another experiencing organization [21, 36]. The following analysis holds the nominated local/unit conditions fixed, including any developed reasoning and actual-uptake criteria. It concerns the consistency and selection of assignments, not a detector for experience.

B.1 Exact unanchored assignment

Let $L \subseteq V$ be locally qualifying candidate activities. Write $u \rightarrow v$ for an eligible other-unit formative contribution, and

$$\text{Post}_L(E) = \{v \in L : \exists u \in E, u \rightarrow v\}.$$

The biconditional experiential-contributor recipe identifies membership with local qualification together with an admitted experiential contributor:

$$E = \text{Post}_L(E). \tag{23}$$

If the contributor condition is asserted only as necessary for experience, the appropriate statement is instead $E \subseteq \text{Post}_L(E)$. This weaker rule still makes every admitted activity have an admitted predecessor. A nonempty assignment on well-founded ancestry is therefore impossible under either rule. The fixed-point classification below concerns the biconditional equality, which additionally requires admission of every locally qualifying successor of an admitted contributor. Necessary-only assignments need not be forward closed: with $a \leftrightarrow b$ and $b \rightarrow c$, the set $E = \{a, b\}$ satisfies strict inclusion into $\text{Post}_L(E) = \{a, b, c\}$.

Proposition B.1 (Existence, uniqueness and finite classification). *The empty assignment always solves (23). If formative ancestry within a hypothetical nonempty solution is well-founded, no such solution exists, so empty admission is unique. On a finite graph, all solutions are forward reachability closures of unions of cyclic strongly connected components (SCCs) in the graph induced by L . Hence a nonempty solution exists exactly when that graph has a cycle; the unique assignment is empty exactly when it is acyclic. Exactly one nonempty solution exists exactly when there is one cyclic SCC, but the empty solution remains.*

Proof. $\text{Post}_L(\emptyset) = \emptyset$. A nonempty solution under well-founded ancestry would have a minimal member, although membership requires another member as predecessor, a contradiction.

For the finite classification, a fixed point is forward closed inside L , and every member has a predecessor in it. Following predecessors in a finite set reaches a cycle, so every member is reachable from a cycle in that set. Forward closure includes its whole SCC and all qualifying successors. Conversely, the forward closure of any chosen cyclic components is closed under successors, and every member has a predecessor on a generating cycle or on its path from one. It is a fixed point. The existence/empty-uniqueness conclusions follow. One cyclic SCC generates only its closure besides empty. With at least two, choose a terminal cyclic SCC in the condensation's cyclic reachability order; its closure omits another cyclic SCC, whose addition gives a different nonempty fixed point. $\square$

The greatest finite solution contains all qualifying successors of qualifying cycles, equivalently vertices whose backward path entirely within L reaches such a cycle. Descending iteration from L computes it. The path must remain inside local qualification; a nonqualifying intermediate contributor cannot transmit justification under this equation. These are elementary fixed-point/graph consequences within the established monotone framework [47].

The incompatible premise combination is universal already-experiencing formative dependence, well-founded experiential ancestry, and at least one experience. Strict temporal precedence alone is not always well-founded on an infinite domain; a finite strictly ordered developmental event model is well-founded. On the integer-indexed infinite graph $n - 1 \rightarrow n$, both empty admission and admission of all vertices satisfy the equation without cycles. That extra ancestry avoids a first element but supplies neither evidence for the physical history nor justification of the nonempty assignment. Choosing the greatest fixed point similarly adds a constitutive selection rule, rather than deriving experiential admission.

B.2 Independent anchors and nonrecursive development

Let $B \subseteq L$ be independently admitted activities. An anchored rule explicitly changes the condition to

$$E = B \cup \text{Post}_L(E).$$

Write $R(S)$ for forward closure in the graph induced by L , including zero-length paths.

Proposition B.2 (Anchored scope). *On a finite graph the solutions are exactly $R(B \cup C)$ for unions C of cyclic SCCs. The least solution is $R(B)$; it is unique exactly when the induced graph on $L \setminus R(B)$ is acyclic. On any well-founded formative relation the unique anchored solution is $R(B)$.*

Proof. Every fixed point contains B and is forward closed, hence includes $R(B)$. A member outside $R(B)$ cannot have a predecessor inside it; otherwise it too is reachable. In a finite residual set, predecessor iteration reaches a cycle there, giving precisely the stated form. Such closures conversely satisfy the equation. A residual cycle produces a strictly larger solution; its absence leaves only $R(B)$. In the well-founded case, $R(B)$ is fixed and a minimal member of any excess solution outside it can have a predecessor neither inside nor outside $R(B)$, a contradiction. $\square$

An adult assumed independently to experience is therefore an anchor for a conditional application, not something admitted by the unanchored universal rule. The application in Section 4 does not derive a universal origin. Fundamental awareness is not silently relabeled as an individuated experiencing anchor.

A different, nonrecursive developmental variant is

$$D_{\text{rel}}(A, J) := \exists B \neq A \text{ CausalFormation}(B \rightarrow \text{Scaffold}_A \text{ operative in } J).$$

It requires actual formation by another organization, without requiring the contributor already to experience. Coupled with developed reasoning and the local/unit recipe, it provides a scoped proposed constitution for reasoning-organized episodes. This changes the contributor premise. Relational formation is mandatory only if that variant is chosen; it is neither established universally nor conjoined here to SPC-2. Human linguistic competence, broader conceptual inference and actual uptake remain different predicates. Adult agrammatic calculation can survive severe acquired grammatical loss, but that finding does not establish developmental independence from language [49]. A particular social-learning benefit likewise does not prove universal experiential-contributor necessity [14].

B.3 Mutual development without circular experiential admission

Two learning organizations can form a particular reasoning scaffold together without their learning equations presupposing experiential status. Give them the class of all 16 binary truth functions. One receives grounded examples $00 \mapsto 0, 01 \mapsto 1$, the other $10 \mapsto 1, 11 \mapsto 0$. Each initially has four consistent hypotheses. Positive-delay exchange supplies all four examples, uniquely identifying XOR. The learned operation can then be used on novel nested expressions: induction gives output $\sum_i x_i \bmod 2$ for a left-associated expression of bits. Enumerating all expressions with three through nine leaves gives 1016 cases. Withholding the other's evidence leaves four candidates under the same identification protocol.

The construction counts initial concepts, sensor grounding, memory, message labels, inference architecture and composition ability. It acquires a particular operative scaffold, not all reasoning from nothing, and does not establish that early contributors lack every possible experience. It supplies the nonrecursive developmental predicate without proving a consciousness threshold. Under the unchanged well-founded experiential-contributor rule, the universal assignment remains empty.

Feedback between extended activities does not repair that result. Exchanges $A_{t_1} \rightarrow B_{t_2}$ and $B_{t_3} \rightarrow A_{t_4}$ with $t_1 < t_2 < t_3 < t_4$ are causally ordered even if their encompassing intervals form a two-cycle. If the actual contributing tokens must already experience, the well-founded obstruction persists. If later qualification admits the whole earlier interval, one has added a whole-interval admission principle. A physical feedback cycle is not automatically a cycle of experiential justification.

Thus having experience, interpreting an occurrence and explicitly defining or reporting experience must not be conflated. The temporal account uses a qualifying person's actual interpretation while leaving the universal admission, complete character and nested/larger-bearer problems distinct. The source-to-functional-use theorems are independent of all these experiential assignment choices.

C Physical witnesses: where the missing distinctions can live

C.1 Causal release in a field theory

Standard physical construction and application of established identification bounds, not a new ontology theorem.

Consider a free massive Klein–Gordon field in $3 + 1$ -dimensional Minkowski spacetime, a reference vacuum state ω_0 , and real compactly supported smooth test functions f, g . Set conventions

$$[\Phi(f), \Phi(g)] = i\Delta(f, g)I, \quad W(af) = \exp(ia\Phi(f)).$$

Prepare $\omega_{\pm}(A) = \omega_0(W(\pm af)^*AW(\pm af))$. If the support of f is spacelike separated from the entire bounded early observation region O , microcausality gives $[W(af), A] = 0$ for every early local observable A . Hence $\omega_+(A) = \omega_-(A) = \omega_0(A)$. Admit finite adaptive early protocols with the same initially independent apparatus and random-seed laws in both preparations, causal composition, and a complete transcript effect in the local algebra $\mathcal{A}(O)$ for each transcript. Each such effect commutes with the preparation, so all early transcript probabilities agree. Local probe couplings and their induced instruments provide a physical framework in which these localization and composition obligations can be checked [8]; they are not consequences of calling an arbitrary instrument local. No tensor-product factorization of local QFT algebras is assumed.

Choose a later smearing g with $\Delta(f, g) \neq 0$. The scalar commutator makes the Baker–Campbell–Hausdorff expansion terminate:

$$W(af)^* \Phi(g) W(af) = \Phi(g) + a\Delta(f, g)I.$$

In the vacuum, $\Phi(g)$ has a centered Gaussian law of variance $v = \omega_0(\Phi(g)^2) > 0$. The two prepared laws are therefore $N(\pm\mu, v)$, $\mu = a\Delta(f, g)$. Thresholding at zero has equal-prior error

$$\delta = \Phi_N(-|\mu|/\sqrt{v}), \quad \text{TV}(N(\mu, v), N(-\mu, v)) = 1 - 2\delta. \quad (24)$$

Here Φ_N is the standard normal distribution function. Smooth coherent excitations have finite energy in this model for finite amplitude. A material detector, a bound on resources, and retained threshold records are additional engineering assumptions. The ideal observable is not itself a completed laboratory experiment.

Thus independently specified relativistic dynamics permit identical early local statistics and different later statistics. If one common prediction law based only on that early operational class must fit both preparation-conditioned later laws, its worst-case TV error is at least $(1 - 2\delta)/2$, by the half-TV bound in *Scaled or Leaky* [34, Theorem 5.2] and *Constituted Agency* [20, Section 7.1, p. 26]. This uniform conditional requirement does not invalidate the correct stochastic marginal prediction for one fixed prior mixture of preparations. This is a specified-model witness and a conditional empirical argument against a claim that the early tube already suffices for that target. The extra structure can be an ordinary field excitation outside the early tube. The result does not require another dimension or an external observer.

The time-slice axiom does not refute this example. Chilian and Fredenhagen’s result concerns a neighborhood of a Cauchy surface, and in the interacting case formal renormalized perturbation theory [4]. It does not give a finite observer access to every degree of freedom on that surface. Conversely, a complete Cauchy description in a well-posed classical model is a counterexample to a universal assertion that every present description must be dynamically incomplete.

C.2 Unitary retrieval after local forgetting

Take three qubits S, E, R initially in $|x, 0, 0\rangle$, $x \in \{0, 1\}$. First apply $\text{CNOT}_{S \rightarrow E}$, then $\text{SWAP}_{S, R}$. The state becomes $|0, x, x\rangle$. The reduced state of S is now the same $|0\rangle\langle 0|$ for either preparation. Applying the same later $\text{CNOT}_{E \rightarrow S}$ gives $|x, x, x\rangle$ and perfectly restores the distinction in S .

This is a direct finite example of nonclosure of the present reduced state under an admitted later operation. The full unitary state never lost the distinction. Ready registers and a scheduled interaction catalogue are resources. For any Hermitian involution U , the finite Hamiltonian $H = \pi\hbar(I - U)/(2\tau)$ is positive semidefinite and satisfies $e^{-iH\tau/\hbar} = U$. This implements each gate over a specified interval; it does not by itself construct an autonomous clock or relativistic material apparatus. Autonomous quantum-record constructions provide more elaborate finite measurement programmes under their own assumptions [22], rather than retroactively making this schedule autonomous.

The relevant external comparison is the operational quantum Markov condition: intervening to break the local system’s causal connection with its past can leave future statistics dependent on earlier operations through an environment [19]. A reduced density matrix at one time does not specify every multitime intervention law. The circuit instantiates this familiar mechanism; no priority is claimed.

C.3 The RS2 witness and its proper role

Take the positive-tension, Z_2 -symmetric RS2 model with pure five-dimensional Einstein gravity, a negative bulk cosmological constant, and no additional bulk matter. The readout is the gauge-reduced instantaneous induced brane Cauchy data and brane matter data; the admissible bulk initial-data class includes finite-energy transverse-traceless wave packets. Under these model assumptions, the effective equation has the familiar structure [30, 42]

$$G_{\mu\nu} = -\Lambda_4 g_{\mu\nu} + \kappa_4^2 T_{\mu\nu} + \kappa_5^4 \Pi_{\mu\nu} - E_{\mu\nu}. \quad (25)$$

The projected bulk Weyl tensor $E_{\mu\nu}$ need not be determined by instantaneous brane data. Paper 7 already constructs bulk-wave nonclosure and discusses adaptive protocol equivalence. Re-expressing that result as a block history is an application. It does not newly prove hidden dimensions, and changing futures distinguish the corresponding complete histories. The field and qubit examples show that the access/nonclosure structure is more general than RS2. The RS2 branch contributes a specified gravitational realization and conditional residues, rather than a universal argument from local ignorance to a unique bulk.

Persistence of a prepared record. For a deposited state ρ_i the holding requirement is $\Phi_t(\rho_i) = \rho_i$ over the nominated interval. It need not be equivalent to conservation of its Heisenberg projection. For amplitude damping with jump $L = \sqrt{\gamma}|0\rangle\langle 1|$, the ground state P_0 is stationary but $\mathcal{L}^*(P_0) = \gamma P_1 \neq 0$. A zero record Hamiltonian/channel supplies both stationarity and projection conservation in an ideal held register; either property must be specified rather than inferred from the other without further assumptions.

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