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Causality and no-go theorems

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Abstract

The aim of the paper is to investigate the role played by causality, and more specifically the no-signaling condition, in the assessment of the quantum theory. To this end, we discuss why it is important that even a non-relativistic theory such as Quantum Mechanics doesn't imply a violation of this condition. Then, we use this argument to prove an original result stating that the destructive behaviour of the measurement process on the entanglement properties of quantum systems is a necessary and unavoidable feature of the quantum theory. Finally, we critically review the no-cloning theorem. The original formulation of the theorem states that a linear quantum cloning machine, designed in order to successfully clone states that coincide with appropriate basis vectors, fails to copy states that are a non-trivial superposition of those basis vectors; we will furthermore prove that such a linear cloning device, even with the hypothesis that it can only clone basis vectors successfully, may provide a violation of the no-signaling condition and therefore cannot exist.

Keywords: Quantum mechanics, Entanglement, Quantum nonlocality, Quantum cloning [1]

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1 Introduction

A distinctive feature of contemporary science is the production of negative results, called no-go theorems [Dardashti, 2021], that *a priori* restrict the accessibility of some theoretical and experimental outcomes, Gödel's incompleteness theorems being a great example.

Quantum mechanics (QM), perhaps due to its own intrinsic paradoxicality, turned out to be very fruitful for no-go theorems. While on the one hand the questions of QM locality [Griffiths, 2011, 2020, 2021; Lambare, 2021] and realism [Gill, 2023; Gill and Lambare, 2022, 2023; Kupczynski, 2020] are still ardently debated to this day, on the other hand several concerns have been raised regarding the deep significance of no-go theorems [Laudisa, 2014; Oldofredi, 2018]. Specifically, since the ontology on which the quantum theory is based still appears elusive, it is unclear what no-go theorems really tell us about the (quantum) world. Thus, rather than feeding further the nowadays nourishing industry of these theorems, it may be a good strategy to focus on clarifying the quantum ontology, and only subsequently wonder whether these theorems are still worth pursuing. While in our opinion this view appears very sound, there is a subclass of these theorems, the one including the no-cloning theorem and the no-deletion theorem, that has got relevant consequences on the field of quantum information, and feels hence worth pursuing immediately regardless of the opacity of the ontology. Nonetheless, the discussion on causality naturally arises from this topic and relates QM to Special Relativity (SR), whose ontology is much clearer and might even end up contributing to the clarification of the quantum ontology.

With "causality" in this paper we refer to the no-signaling condition, i.e. the impossibility of superluminal communication. We note that for two space-like separated events it is always possible to identify an inertial reference frame where their time ordering is inverted. If we want the physical world to make sense, we have to assume that space-like separated events cannot have a causal relation with each other. Otherwise, by means of an appropriate Lorentz transformation, we could see an effect preceding its physical cause.

This paper is devoted to clarifying the role played by the no-signaling condition within the frame of these no-go theorems, and it is organized as follows. In Section 2 we will briefly review the use of this condition in well known no-go theorems and we will try to validate such an employment from an epistemological point of view. Specifically, we will try to clarify why, even though standard QM is not a relativistically covariant theory, we are still concerned by the possibility of superluminal signaling phenomena arising inside its framework. In Section 3 we will present an original result regarding the destructive behaviour of the measurement process on the entanglement properties of quantum systems. Finally, in Section 4 we will review in details the no-cloning theorem related to the no-signaling condition, and we will show that it involves an *a priori* impossibility, regarding the cloning process of a quantum state, even stronger than the one discussed by the authors of the theorem.

2 No-go theorems cast under the light of causality

The no-signaling argument has played a significant role in the history of no-go theorems. In particular, as we will explicitly show in Section 4, if the no-cloning theorem is false [Wootters and Zurek, 1982], two observers, namely Alice and Bob, can employ an algorithm that allow them to communicate superluminally [Herbert, 1982], and it is interesting to note that this may be the very reason that led to the formulation of the theorem [Peres, 2003]. Similarly, if the no-deletion theorem [Pati and Braunstein, 2000a] is false, a different algorithm allows for superluminal signaling [Pati and Braunstein, 2000b]. The no-signaling condition imposes a bound on imperfect cloning [Gisin, 1998] processes in terms of the similarity of imperfect clones to the original system, and on probabilistic cloning [Pati, 2000] and probabilistic deletion [Chakrabarty et al., 2006] processes in terms of the probability to observe a successful process. It has been shown that the basic dynamical properties of QM can be derived from its static properties with the implementation of the no-signaling condition [Simon et al., 2001], and this result puts significant constraints on possible non-linear modifications of QM that don't violate the no-signaling condition. More recent results invoking this condition regard the exponential scaling of accuracy for a port-based teleportation [Kubicki et al., 2019] and the impossibility to design a universal quantum superimposer [Bandyopadhyay, 2020].

In light of the above discussion, it is clear that the no-signaling argument has been and is still being widely employed in the production of no-go theorems. However, an epistemological problem emerges. The behaviour of a quantum object is described by the Schrödinger equation, which is not a Lorentz invariant equation, thus QM is not a relativistically covariant theory. Moreover, QM includes a far more direct violation of causality: a quantum object has a non-zero probability to propagate outside the lightcone due to the ordinary time evolution of its wavefunction [see Peskin and Schroeder, 1995, Section 2.1]. We may ask, then, why there seems to be a "good" sort of violation of causality that we can tolerate and doesn't prevent us to still make a good use out of QM, and a "bad" one, employed in many no-go theorems, that we cannot accept and, if we find it hidden somewhere in the framework of QM, it will immediately disqualify the theory as a sound one. It is worth quoting D. J. Griffiths [Griffiths and Schroeter, 2018, Section 12.4]: *"Indeed, if you could build a cloning device, quantum mechanics would be out the window. For example, it would then be possible to send* *superluminal messages using the EPRB experiment."*

But why are we concerned by superluminal messages in a non-relativistic theory in first place, while the same theory implies that even a particle may escape the light-cone? We will try in the following to give an answer.

Being a non-relativistic theory, standard QM rigorously holds only for small velocities compared to the velocity of light. It is interesting to note that it would become exactly true only for a null velocity, where relativistic corrections vanish, except that the uncertainty principle forbids a quantum objects to have a null velocity. So QM is never really true, and only for small velocities it gives an approximately good description of reality. With the "bad" kind of violation of causality, however, no approximation has been performed. If it is predicted by QM, it is so for any velocity of the quantum objects involved. This means that, if such a violation is predicted by QM, then the theory is simply inadequate to the description of reality, as long as we consider correct the description given by SR.

It is somewhat similar to function calculus: when representing a function through a Fourier series, we may restrict its domain to the intervals we are interested in, in order to avoid the ones in which we are not satisfied by the representation (such as points of discontinuity). Considering QM with the "bad" violation , the flaw is extended to the whole domain, and there is no interval in which we may be satisfied by the outcome, therefore we are forced to discard the theory entirely and look for a different theory that doesn't contemplate this spooky behavior.

The main point is that scientific theories are instruments that we use to describe reality. If we have reasons to strongly believe in the results of a theory (such as SR) and another theory necessary to the picture explicitly contradicts it (such as QM with the "bad" violation), we cannot consider reality actually described.

3 A measurement process must deplete the entanglement properties of a quantum system

The no-cloning and no-deletion theorems are together implied by the more general no-signaling theorem [Bruss et al., 2000], according to which an observer cannot send information to another observer through a measurement of the subsystem of an entangled quantum system. It is important to note that this theorem only takes a single measurement into account, and does rightly so since quantum measurements notoriously alter the entanglement properties of the observed systems. However, if a fictitious device is capable of measuring the state of the system without altering its entanglement, one might wonder whether it is possible to send superluminal signals through successive measurements of the same system, thus bypassing the no-signaling theorem. As it will be soon proven, this is exactly the case: measuring a quantum state without altering its entanglement properties allows an algorithm for superluminal signaling, and it is therefore impossible.

3.1 Motivation and formalism

In order to prove this statement (in the particular but easily generalizable case of the spin projections for Bell pairs), we take into account the behavior of spin one-half particles. The matrix representation for spin projection operators is shown below.

Operator
$$S_z = \frac{\hbar}{2}\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} ; \tag{1}$$

Eigenfunctions and eigenvalues
$$|\uparrow\rangle = \begin{pmatrix} 1 \\ 0 \end{pmatrix} \qquad \lambda = +\frac{\hbar}{2}, \tag{2}$$
$$|\downarrow\rangle = \begin{pmatrix} 0 \\ 1 \end{pmatrix} \qquad \lambda = -\frac{\hbar}{2}. \tag{3}$$

Operator
$$S_x = \frac{\hbar}{2}\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} ; \tag{4}$$

Eigenfunctions and eigenvalues
$$|+\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ 1 \end{pmatrix} \qquad \lambda = +\frac{\hbar}{2}, \tag{5}$$
$$|-\rangle = \frac{1}{\sqrt{2}}\begin{pmatrix} 1 \\ -1 \end{pmatrix} \qquad \lambda = -\frac{\hbar}{2}. \tag{6}$$

Given the state of a particle, it is often useful to compute the probability of obtaining one of the possible values for a particular observable. For instance, we get:

$$|\langle + | \uparrow\rangle|^2 = |\langle - | \uparrow\rangle|^2 = |\langle + | \downarrow\rangle|^2 = |\langle - | \downarrow\rangle|^2 = \frac{1}{2} \tag{7}$$
$$|\langle \uparrow | +\rangle|^2 = |\langle \uparrow | -\rangle|^2 = |\langle \downarrow | +\rangle|^2 = |\langle \downarrow | -\rangle|^2 = \frac{1}{2} \tag{8}$$

These relations indicate that, when a particle is in a pure eigenstate of the spin projection operator over the x- or z-axis, measuring the spin projection on the other axis can give either value $+\hbar/2$ or $-\hbar/2$ with a 50% probability. The same holds for the y-axis, but it is not relevant to the present discussion. Due to space isotropy, Eqs. (7)-(8) hold for any right-handed set of axes. It is also important to note that a measurement performed on the subsystem of an entangled quantum system also collapses the complementary subsystem. In particular, given the electron-positron singlet state

$$\frac{1}{\sqrt{2}}(|\uparrow\downarrow\rangle - |\downarrow\uparrow\rangle), \tag{9}$$

measuring the z-spin of the electron collapses the global system into the state

$$|\uparrow\downarrow\rangle \text{ or } |\downarrow\uparrow\rangle, \tag{10}$$

while notoriously disentangling the system in the process. However, even though they are always correlated, the collapsing of the wavefunction and the breaking of the entanglement are ontologically two distinct processes. It couldn't be otherwise, since the wavefunction and its collapse are a matter of formalism and description, while the entanglement is a real, fundamental feature of QM [Truda et al., 2022]. The next Subsection proves that allowing the conservation of the entanglement processes when the subsystem of an entangled quantum system is measured would constitute a reliable channel for superluminal signaling, henceforth the depletion of the entanglement during a measurement process is a necessity of nature.

3.2 Proof

Let us assume that Alice and Bob are once again trying to cheat the no-signaling condition. They set up their EPRB apparatus in such a way that Alice can measure the z-spin component of her particle and Bob the x-spin component of his one. Let us suppose that both of them have a fictitious device at hand that allows them to perform measurements without altering the entanglement of the system. Before splitting up by an arbitrary distance, Alice and Bob synchronize their clocks taking into account any relativistic correction and establish a convention.

a) At time $t = 0$ Alice decides whether to send Bob a bit 0 or a bit 1. If she decides to send the bit 0, she does not perform any measurements. If she decides to send the bit 1, she measures the z-spin of her particle and repeats the measure every two seconds.

b) At time $t = 1s$ Bob measures the x-spin of his particle and repeats the measure every two seconds.

Supposing that they succeed in applying this convention, the series of measurements follows the pattern below.

$$t = 0 \rightarrow \text{Alice measures } S_z^A$$

$$t = 1s \rightarrow \text{Bob measures } S_x^B$$

$$t = 2s \rightarrow \text{Alice measures } S_z^A$$

$$t = 3s \rightarrow \text{Bob measures } S_x^B$$

It is important to note that, thanks to the ideal device employed in the measurements, the Bell pair remains entangled even after an arbitrary number of measurements. Keeping this convention in mind, Bob checks the results obtained from his measurements.
If he has always obtained the same value ($+\hbar/2$ or $-\hbar/2$), the state of his particle has not repeatedly collapsed due to the collapsing of the state of Alice's particle, so Alice has not performed any measurements and Bob receives a bit 0.
If he has obtained random values, the state of his particle has been collapsing due to the collapsing of Alice's particle, so Alice has performed her measurements and Bob receives a bit 1.
If Alice and Bob are sufficiently far apart from each other, they have achieved a form of superluminal signaling and thus violated causality.

3.3 Discussion

It is now clear that the destructive behavior of the measurement process on the entanglement properties of quantum systems is not an accidental feature to add to the list of eccentricities of the quantum theory, but it is an unavoidable necessity of nature. In other words, when looking for an alternative theory to QM, such as Bohmian mechanics, one can't expect it to somehow preserve the entanglement of a system upon measurement.

While in the field of quantum information [Bub, 2023] the no-cloning theorem implies that unknown data based on a set of qubits cannot be duplicated, this new result implies that data based on entangled qubits cannot be read out without being consumed in the process, and, with the point of view of quantum cryptography, that a communication based on entangled qubits cannot be intercepted without being distorted. Any attempt to produce a technology to perform such tasks is going to fail.

In regard to the algorithm employed by Alice and Bob, it can be argued that it is not perfect: there is a $2^{-(N-1)}$ margin to receive the wrong bit, N being the number of measurements performed by each of the observers, that represents the possibility that the state of Bob's particle happens to collapse on the same state again and again even though Alice is performing her measurements. This, however, doesn't make the algorithm any less reliable and, as we will show in the next Section, the no-cloning theorem contemplates the same flaw. Also, a single measurement tells Bob nothing about Alice's decision to send a bit 0 or 1, in accordance with the no-signaling theorem.

It might seem that the argument presented is quite specific, as it relies on specific properties of the system considered, i.e. an $S = 0$ spin singlet state. We point out, instead, that this result is generalizable to any entangled system consisting of at least two proper subsystems. We don't implement such a generalization since it would be pedantic to consider a generic entangled system, together with a generic operator with at least two different non-degenerate eigenstates on which the wavefunction that describes the system shall collapse upon measurement. Thus, we believe that the specific – but encompassing the whole phenomenon – case here described is the best way to present our claim.

Finally, we note that recently a scheme has been developed to experimentally generate entangled states by using quantum walks with multiple coins [Li and Shang, 2021]. In the light of the above consideration, such states are involved by our result.

4 Critical review of the no-cloning theorem

The hypothetical quantum cloning machine (QCM) is supposed to be able to produce perfect copies of states that totally overlap with one of the basis vectors, i.e., when they are decomposed onto an orthonormal basis, only a single coefficient is one and all the others are zero. As a consequence of linearity, it is proven that the QCM fails to clone unknown states [Wootters and Zurek, 1982] when they happen to be a non-trivial superposition of basis vectors. However, there seems to be a flaw to the claim: according to QM, the basis functions used to write a state as linear combination are arbitrary. From now on we'll just consider spin projection operators for spin $1/2$ particles. Given an arbitrary mixed state of these operators, there is always a basis according to which the state totally overlaps with a basis vector. Trivially, the given state itself can be used as a basis vector. If we let the QCM act on the superposition state, then, it fails to clone it, but if we change the basis so that the state overlaps with a basis vector, the QCM may clone it successfully. Therefore, it seems that the definition of the QCM is not sound. It makes no sense that the QCM should act on the same state differently, giving a different output, when we write the same state on a different basis.

The point that validates the definition is that the QCM cannot be universal and must be instead specifically designed in order to copy a set of vectors forming a chosen orthogonal basis. That basis is thus fixed and cannot be changed, and a generic state must be written as a linear combination of those basis vectors alone, those for which the QCM has been designed. This is crucial for the point we are going to prove.

Having clarified the framework that validates the no-cloning theorem, let us consider another meaning to the theorem that goes beyond the fundamental frame of QM. We will show that, if this theorem is false, then there is an algorithm that allows superluminal signaling [Herbert, 1982].

Let us call Alice and Bob the experimenters of an EPRB apparatus. If Alice wants to send a bit 1 to Bob, she measures the z-component of the spin of her particle; if she wants to send a bit 0, she does not perform any measurement. Through a QCM designed in order to clone eigenstates of the z-component of the spin projection operator, Bob produces N clones of his particle and measures the z-component for all of them. If they all give the same result, $+\hbar/2$ or $-\ \hbar/2$, then he receives a bit 1 (there is a negligible probability $2^{-(N-1)}$ to get the wrong bit, which takes into account the possibility that all the clones happen to collapse in the same state even though Alice has not performed any measurements). If they give random results, he receives a bit 0. Since there could be any arbitrary distance between Alice and Bob, it makes sense to suppose that the events of measurements on the sides of the EPRB apparatus are separated by a space-like interval, thus violating causality.

While there is no question that this argument holds, further investigation reveals a deeper implication: it also rules out the original cloning machine with the hypothesis of linearity. Indeed, if the QCM copies basis states perfectly and superposition states poorly, Bob is still able to receive (superluminally) the correct bit. If the quantum state Bob is cloning happens to overlap with an eigenstate of the z-component of the spin operator (i.e. Alice performed a measurement of the z-component of the spin of her particle), then all the clones give the same result when he measures them. If the quantum state he is cloning happens to be in a superposition of eigenstates of the z-component of the spin operator, then there seem to be two possibilities.

1. If the output of the cloning machine for this superposition of states is somehow distinguishable from the output for the pure eigenstate, Bob can distinguish it as long as he obtains different values from his measurements, and he correctly receives a bit 0.

2. If the output of the cloning machine is indistinguishable from the output for the pure eigenstate, Bob obtains the same value from all measurements and receives the wrong bit 1. However, even if a particular superposition of states is poorly cloned to a pure eigenstate output, then there is a violation of linearity. In fact, the hypothesis of linearity implies that all the components of a superposition of states must not be annihilated by the cloning process and, even though the output state can be a distorted copy of the input one, its dimensionality must still be the same, so we need to exclude this possibility.

The conclusion is that, as a consequence of linearity, not only unknown superposition states can't be perfectly cloned, as the authors of the no-cloning theorem have already claimed, but also pure basis states of the chosen basis can't be cloned as long as they are unknown. This removes from the picture the cloning process of unknown states as a whole, for both eigenstates of an observable and superpositions of those eigenstates. The only possibility left is that of a QCM that produces the same output state whatever the input, so that, when the input state happens to be already congruent to the chosen output, it may be successfully cloned. However, this is not a cloning process at all and the implied device is really a "quantum printer" more than a quantum cloning machine.

An objection might be that the cloning of an eigenstate of an observable can be done in a trivial way: the state can be measured and its state can be printed onto a blank state. The counter-objection is that the state to be cloned might be a superposition and may collapse onto an eigenstate during the measurement, and it cannot be used for superluminal signaling anymore. The cloning of a known state is a trivial process anyway; it is the unknownness of the state that brings on the challenge. Even in the original proof of the no-cloning theorem, the cloning process is assumed to be linear precisely because it is supposed to be ruled by the Schrödinger equation and not a measurement process, which is not linear [Ferraioli and Noce, 2019].

Moreover, this argument fails if we allow the quantum clone to be entangled with the original system. An output of this kind does not allow for more than one independent measurement, as a consequence of the new result proven in Section 3, thus it is useless for superluminal signaling. One may wonder, however, whether the entangled clone is a legitimate, actual clone of the original state, since the former shows an entanglement property that the latter does not exhibit.

5 Conclusions

In this paper we have claimed that the no-signaling condition is a sound argument even though QM is not a relativistically covariant theory and we have employed it in the proof of an original no-go result. It is now clear that the destructive behavior of the measurement process on the entanglement properties of quantum systems is a necessity related to Special Relativity by the no-signaling condition. We have also shown that the no-signaling condition forbids the cloning process of unknown quantum states as a whole, and not only for superposition states as it was already proven within the no-cloning theorem.

For the sake of completeness, we mention that we have implicitly assumed that causal relations between events is frame-invariant, the causes precede their effects and the relation of precedence between events is given by the time-ordering of a Lorentz frame. For a criticism on these assumptions, see the Stanford Encyclopedia of Philosophy [Faye, 2021; Friederich and Evans, 2022]. These requirements, sometimes called the microscopic causality principle, are the mathematical statement of the fact that no signal can be exchanged between two points separated by a space-like interval, and therefore that measurements at such points cannot interfere with each other. Moreover, we stress that when the axiomatic approach to Quantum Field Theory, i.e. Relativistic Quantum Mechanics, is concerned, the assumption that local field observables commute or anticommute for space-like separations is a consequence of the mentioned locality assumption [see Schweber, 1961, page 723].

References

S. Bandyopadhyay. Impossibility of creating a superposition of unknown quantum states. *Phys. Rev. A*, 102:050202, Nov 2020. doi: 10.1103/PhysRevA.102.050202. URL `https://link.aps.org/doi/10.1103/PhysRevA.102.050202`.

D. Bruss, G. M. D'Ariano, C. Macchiavello, and M. F. Sacchi. Approximate quantum cloning and the impossibility of superluminal information transfer. *Phys. Rev. A*, 62:062302, Nov 2000. doi: 10.1103/PhysRevA.62.062302. URL `https://link.aps.org/doi/10.1103/PhysRevA.62.062302`.

J. Bub. Quantum Entanglement and Information. In E. N. Zalta and U. Nodelman, editors, *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University, Summer 2023 edition, 2023. URL `https://plato.stanford.edu/archives/sum2023/entries/qt-entangle/`.

I. Chakrabarty, S. Adhikari, and B. S. Choudhury. Probabilistic exact deletion and probabilistic no-signalling. *Phys. Scr.*, 74(5):555, 2006. doi: 10.1088/0031-8949/74/5/012. URL `http://dx.doi.org/10.1088/0031-8949/74/5/012`.

R. Dardashti. No-go theorems: What are they good for? *Studies in History and Philosophy of Science Part A*, 86:47–55, 2021. ISSN 0039-3681. doi: https://doi.org/10.1016/j.shpsa.2021.01.005. URL `https://doi.org/10.48550/arXiv.2103.03491`.

J. Faye. Backward Causation. In E. N. Zalta, editor, *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University, Spring 2021 edition, 2021. URL `https://plato.stanford.edu/entries/causation-backwards/`.

A. G. Ferraioli and C. Noce. The measurement problem in quantum mechanics. *Science and Philosophy*, 7:41–58, 2019. doi: 10.23756/sp.v7i1.462. URL `http://dx.doi.org/10.23756/sp.v7i1.462`.

S. Friederich and P. W. Evans. Retrocausality in Quantum Mechanics. In E. N. Zalta and U. Nodelman, editors, *The Stanford Encyclopedia of Philosophy*. Metaphysics Research Lab, Stanford University, Winter 2022 edition, 2022. URL `https://plato.stanford.edu/entries/qm-retrocausality/`.

R. Gill. Further comments on 'Is the moon there if nobody looks? Bell inequalities and physical reality'. *Qeios*, 2023. ISSN 2632-3834. doi: 10.32388/OLGL3Z. URL `https://doi.org/10.32388/OLGL3Z`.

R. D. Gill and J. P. Lambare. General commentary: Is the moon there if nobody looks—bell inequalities and physical reality. *Frontiers in Physics*, 10, 2022. ISSN 2296-424X. doi: 10.3389/fphy.2022.1024718. URL `https://doi.org/10.3389/fphy.2022.1024718`.

R. D. Gill and J. P. Lambare. Kupczynski's contextual locally causal probabilistic models are constrained by bell's theorem. *Quantum Reports*, 5(2): 481–495, 2023. ISSN 2624-960X. doi: 10.3390/quantum5020032. URL `https://www.mdpi.com/2624-960X/5/2/32`.

N. Gisin. Quantum cloning without signaling. *Phys. Lett. A*, 242:1, 1998. doi: 10.1016/s0375-9601(98)00170-4. URL `http://dx.doi.org/10.1016/S0375-9601(98)00170-4`.

D. J. Griffiths and D. F. Schroeter. *Introduction to Quantum Mechanics*. Cambridge University Press, 3 edition, 2018. doi: 10.1017/9781316995433.

R. B. Griffiths. EPR, Bell, and quantum locality. *American Journal of Physics*, 79(9):954–965, 09 2011. ISSN 0002-9505. doi: 10.1119/1.3606371. URL `https://doi.org/10.1119/1.3606371`.

R. B. Griffiths. Nonlocality claims are inconsistent with Hilbert-space quantum mechanics. *Phys. Rev. A*, 101:022117, Feb 2020. doi: 10.1103/PhysRevA.101.022117. URL `https://link.aps.org/doi/10.1103/PhysRevA.101.022117`.

R. B. Griffiths. Reply to "Comment on 'Nonlocality claims are inconsistent with Hilbert-space quantum mechanics' ". *Phys. Rev. A*, 104:066202, Dec 2021. doi: 10.1103/PhysRevA.104.066202. URL `https://link.aps.org/doi/10.1103/PhysRevA.104.066202`.

N. Herbert. Flash - a superluminal communicator based upon a new kind of quantum measurement. *Foundations of Physics*, 12(12):1171–1179, 1982. doi: 10.1007/BF00729622. URL `https://doi.org/10.1007/BF00729622`.

A. M. Kubicki, C. Palazuelos, and D. Pérez-García. Resource quantification for the no-programing theorem. *Phys. Rev. Lett.*, 122: 080505, Feb 2019. doi: 10.1103/PhysRevLett.122.080505. URL `https://doi.org/10.48550/arXiv.1805.00756`.

M. Kupczynski. Is the moon there if nobody looks: Bell inequalities and physical reality. *Frontiers in Physics*, 8, 2020. ISSN 2296-424X. doi: 10.3389/fphy.2020.00273. URL `https://doi.org/10.3389/fphy.2020.00273`.

J. P. Lambare. Comment on 'Nonlocality claims are inconsistent with Hilbert-space quantum mechanics'. *Phys. Rev. A*, 104: 066201, Dec 2021. doi: 10.1103/PhysRevA.104.066201. URL `https://link.aps.org/doi/10.1103/PhysRevA.104.066201`.

F. Laudisa. Against the 'no-go' philosophy of quantum mechanics. *Eur. J. Philos. Sci.*, 4(1):1–17, 2014. URL `https://doi.org/10.1007/s13194-013-0071-4`.

M. Li and Y. Shang. Entangled state generation via quantum walks with multiple coins. *npj Quantum Information*, 7:70, 05 2021. doi: 10.1038/s41534-021-00401-6. URL `https://doi.org/10.1038/s41534-021-00401-6`.

A. Oldofredi. No-go theorems and the foundations of quantum physics. *J. Gen. Philos. Sci.*, 49:355, 2018. URL `https://doi.org/10.1007/s10838-018-9404-5`.

A. Pati and S. Braunstein. Impossibility of deleting an unknown quantum state. *Nature*, 404:164–5, 04 2000a. URL `https://doi.org/10.1038/404130b0`.

A. K. Pati. Probabilistic exact cloning and probabilistic no-signalling. *Phys. Lett. A*, 270(3-4):103, May 2000. ISSN 0375-9601. doi: 10.1016/s0375-9601(00)00281-4. URL `http://dx.doi.org/10.1016/S0375-9601(00)00281-4`.

A. K. Pati and S. L. Braunstein. Quantum no-deleting principle and some of its implications (unpublished result), 2000b. URL `https://doi.org/10.48550/arXiv.quant-ph/0007121`.

A. Peres. How the no-cloning theorem got its name. *Fortschritte der Phys.*, 51:458–461, 2003. doi: 10.1002/prop.200310062. URL `http://dx.doi.org/10.1002/prop.200310062`.

M. E. Peskin and D. V. Schroeder. *An Introduction to quantum field theory*. Addison-Wesley, Reading, USA, 1995. ISBN 978-0-201-50397-5. URL `https://doi.org/10.1201/9780429503559`. Section 2.1.

S. Schweber. *An Introduction to Relativistic Quantum Field Theory*. Harper international student reprints. Row, Peterson, 1961. URL `https://books.google.it/books?id=2ghRAAAAMAAJ`.

C. Simon, V. Bužek, and N. Gisin. No-signaling condition and quantum dynamics. *Phys. Rev. Lett.*, 87:170405, Oct 2001. doi: 10.1103/PhysRevLett.87.170405. URL `https://link.aps.org/doi/10.1103/PhysRevLett.87.170405`.

L. Truda, A. Trotta, and C. Noce. Can the entanglement be considered a basic concept of quantum mechanics? *Science and Philosophy*, 10:57–69, 2022. doi: 10.23756/sp.v10i1.739. URL `http://dx.doi.org/10.23756/sp.v10i1.739`.

W. K. Wootters and W. H. Zurek. A single quantum cannot be cloned. *Nature*, 299:802, 1982. URL `https://doi.org/10.1038/299802a0`.