Weak Quantum Theory isn't *that* weak

D. Chrastina

I certainly am entertained by Milgrom's new notion of "the importance of isolation from the external environment (the consultation) in order for coherence and decoherence to bring about the possibility of cure." It formalizes the position that homeopaths, and the people who feel a subjective benefit in going to them, have lost contact with reality. Indeed, my experience is that a lack of coherence is often seen in homeopaths with whom I try to interact. I am also pleased to note that Milgrom admits that "the wave functions of orthodox quantum theory represent quantifiably measurable observables of physical particles. This is not what the 'wave-functions' in PPR [patient-practitioner-remedy] entanglement or WQT [weak quantum theory] [1] represent... They represent more qualitative and subjective observables". This makes it clear that WQT [2–5] is useless for answering objective questions such as "does homeopathy work?"

Quantum mechanics is irrelevant to homeopathy,[6] but in any case it seems that Milgrom cannot even follow the relaxed rules of WQT.[5] Greenberger *et al.* give the following as their Eq. (19) based on a gedanken experiment in which a particle at rest at the centre of the apparatus decays into three similar components each with the same energy [7]:

$$|\psi\rangle = \frac{1}{\sqrt{2}}[|a\rangle_1 |b\rangle_2 |c\rangle_3 + |a'\rangle_1 |b'\rangle_2 |c'\rangle_3] \tag{1}$$

Milgrom [8] uses this for his Eq. (1) as a "maximally entangled state" between the patient (*Px*), practitioner (*Pr*) and remedy (*Rx*) each of which are considered to be in either a positive "up" state (respectively: well, helpful, curative) or a negative "down" state (respectively: unwell, unhelpful, non-curative):

$$|\psi_{PPR}\rangle = \frac{1}{\sqrt{2}}[|Px\uparrow\rangle |Pr\uparrow\rangle |Rx\uparrow\rangle + |Px\downarrow\rangle |Pr\downarrow\rangle |Rx\downarrow\rangle] \tag{2}$$

However it is clear that Milgrom misunderstands the meaning of Eq. (1). In the gedanken experiment of Greenberger *et al.*, the fact that the particle is at rest immediately prior to decay constrains the three decay products to have net zero momentum, and since they are considered to each have the same mass then they must be emitted 120° apart. The source is surrounded by six apertures: a, b, and c at 120° separation, and a', b', and c' also at 120° separation (but with the separation between a and a' smaller than 120°). Most decays will lead to the three particles missing the apertures entirely, but a few will lead to the three particles passing through a, b, and c and a few will lead to them passing through a', b', and c'. The point is that states such as $|a\rangle |b'\rangle |c'\rangle$, or even $|a\rangle |a'\rangle |b\rangle$, are forbidden by the rules of conservation of momentum, and the entanglement exists because we know that if a particle has been emitted through a then the other two particles must have been emitted through b and c rather than b' and c'. So of all the possible combinations of apertures only two are physically permitted, and they are represented as the two terms in Eq. (1). As soon as we know that any one particle has gone through a given slit, we immediately know whether the state is $|a\rangle_1 |b\rangle_2 |c\rangle_3$ or $|a'\rangle_1 |b'\rangle_2 |c'\rangle_3$ and in that sense, the superposition given in Eq. (1) has "collapsed" to one of the two equivalent possibilities. Milgrom is wrong in his first response: it is not the case that "the whole entangled state disappears" when the superposition of two entangled states collapses into one state or the other, but it seems he concedes this point in a later response (while maintaining that "the PPR entangled-state wave function does indeed for all intents and purposes disappear" which is still wrong, as will be shown below).

Equation (2) is meant to show entanglement between patient, practitioner and remedy. It would seem to indicate that only two states are allowed. The patient is well, the practioner is helpful and the remedy is curative; or the patient is unwell, the practitioner is unhelpful and the remedy is non-curative. The unphysical entanglement situation here means that if we know that the patient is unwell then the remedy and the practitioner must both be useless. There are no states included in which the remedy and the practitioner are beneficial to an unhealthy patient, who can then flip to the healthy state. There is no time-evolution in any of Milgrom's equations. We are left with the trivial but useless tautology that a helpful practitioner and a beneficial remedy mean a healthy patient - if the remedy is curative then the patient must already be healthy. There is in any case no reason given for such an entanglement (created in Eq. (1) by conservation of momentum) to come about.

In his Eq. (4), Milgrom then goes on to consider PPR without the practitioner, such as might be the case with an over-the-counter homeopathic remedy. (Homeopaths seem to insist on an individualized remedy prescribed by a practitioner, except when it suits them [9, 10].) He represents this by setting

$$|Pr\rangle = 0 \tag{3}$$

and substituting this into Eq. (2) instead of $|Pr\uparrow\rangle$ and $|Pr\downarrow\rangle$. This is invalid, since "0" is not a state: the states of Pr continue to exist whether or not there is anything in them. It is unclear whether Milgrom would rather mean $\langle Pr|Pr\rangle = 0$ (which makes Pr non-normalizable and therefore not a state) or $|Pr\rangle = |0\rangle$, but the second case seems slightly more likely. WQT [2] may have relaxed some of the "constraints" of "orthodox" quantum theory (which connect it to reality) but as long as WQT preserves the algebraic formulation of the latter [11] then these rules are as true for WQT as they are for "orthodox" quantum theory.

There is nothing particularly special about the state $|0\rangle$ - it is conventionally the ground state - and if we assume it to be properly normalized, $\langle 0|0\rangle = 1$, Milgrom's Eq. (4) becomes

$$|\psi_{PPR}\rangle = \frac{1}{\sqrt{2}}[|Px\uparrow\rangle|0\rangle|Rx\uparrow\rangle + |Px\downarrow\rangle|0\rangle|Rx\downarrow\rangle] = \frac{1}{\sqrt{2}}[|Px\uparrow\rangle|Rx\uparrow\rangle + |Px\downarrow\rangle|Rx\downarrow\rangle]|0\rangle \tag{4}$$

such that

$$\begin{aligned}
\langle\psi_{PPR}|\psi_{PPR}\rangle &= \frac{1}{2}(\langle Px\uparrow|\langle Rx\uparrow| + \langle Px\downarrow|\langle Rx\downarrow|)\langle 0|(|Px\uparrow\rangle|Rx\uparrow\rangle + |Px\downarrow\rangle|Rx\downarrow\rangle)|0\rangle & (5)\\
&= \frac{1}{2}(\langle Px\uparrow|\langle Rx\uparrow| + \langle Px\downarrow|\langle Rx\downarrow|)(|Px\uparrow\rangle|Rx\uparrow\rangle + |Px\downarrow\rangle|Rx\downarrow\rangle)\langle 0|0\rangle & (6)
\end{aligned}$$

Since $\langle 0|0\rangle = 1$ by normalization this term can be removed, and when the remaining terms are multiplied out

$$\begin{aligned}
\langle\psi_{PPR}|\psi_{PPR}\rangle &= \frac{1}{2}[\langle Px\uparrow|Px\uparrow\rangle\langle Rx\uparrow|Rx\uparrow\rangle + \langle Px\downarrow|Px\downarrow\rangle\langle Rx\downarrow|Rx\downarrow\rangle] & (7)\\
&+ \frac{1}{2}[\langle Px\uparrow|Px\downarrow\rangle\langle Rx\uparrow|Rx\downarrow\rangle + \langle Px\downarrow|Px\uparrow\rangle\langle Rx\downarrow|Rx\uparrow\rangle] & (8)
\end{aligned}$$

Again, the states should be considered to be properly normalized such that $\langle Px\uparrow|Px\uparrow\rangle = 1$, so that the first half of Eq. (8) is

$$\frac{1}{2}[\langle Px\uparrow|Px\uparrow\rangle\langle Rx\uparrow|Rx\uparrow\rangle + \langle Px\downarrow|Px\downarrow\rangle\langle Rx\downarrow|Rx\downarrow\rangle] = \frac{1}{2}[1\times 1 + 1\times 1] = 1 \tag{9}$$

and if we assume no overlap between up and down states for each of Px and Rx (for example, $\langle Px\uparrow|Px\downarrow\rangle = 0$) the second half of Eq. (8) is

$$\frac{1}{2}[\langle Px\uparrow|Px\downarrow\rangle\langle Rx\uparrow|Rx\downarrow\rangle + \langle Px\downarrow|Px\uparrow\rangle\langle Rx\downarrow|Rx\uparrow\rangle] = \frac{1}{2}[0\times 0 + 0\times 0] = 0 \tag{10}$$

so that overall, $\langle\psi_{PPR}|\psi_{PPR}\rangle = 1$ (meaning only that the ψ_{PPR} state was normalized). In fact it doesn't matter what we use for $|Pr\rangle$ as long as it is a normalized state. The ψ_{PPR} "PPR wavefunction" has not "collapsed to zero" due to the absence of the involvement of the practitioner. The lack of any sort of physical explanation of how the entanglement of Eq. (2) is supposed to be created means there is no way to work out how the case of PPR entanglement without the practitioner should be treated. But of course entanglement between two states is possible in general [12, 13].

It is noted that Milgrom has sometimes [13, 14] treated Px, Pr and Rx as non-commuting operators rather than states, with $[Px, Pr] = iRx$ somewhat analogous to the commutation relation for angular momentum. Also, Milgrom has written [13] $\langle\psi_{PPR}|\Pi r|\psi_{PPR}\rangle = \langle Rx\rangle$ in which $\langle Rx\rangle$ is the 'expectation value' but not of the 'remedy operator' Rx (compare his Eq. [2]) but of Πr. More recently, he has written [14] $\langle\psi_{PPR}|\Pi r|\psi_{PPR}\rangle = \langle(\Delta Sx)\rangle$ where the expectation value of the Πr operator is now 'the overall change in symptoms'. Such shifting of concepts, meanings and rules ruins any connection to quantum theory, whether "weak" [2] or not, and whether "metaphorical" or not.

Another version of Eq. (1) is given as Milgrom's Eq. (8):

$$|\psi_{ent}\rangle = \frac{1}{\sqrt{2}}[|P_{Rx}\uparrow\rangle\,|P_{Pl}\uparrow\rangle\,|P_{O}\uparrow\rangle + |P_{Rx}\downarrow\rangle\,|P_{Pl}\downarrow\rangle\,|P_{O}\downarrow\rangle] \tag{11}$$

Here there is actually some comment on the six missing combinations (forbidden by conservation of momentum in Eq. (1) and thus creating the entanglement) but again with no insight into what mechanism means that only these two states are allowed. If all eight states were allowed there would be no entanglement, since distinguishing between $|a\rangle$ and $|a'\rangle$ would not tell us anything about whether we had $|b\rangle$ and $|b'\rangle$, or $|c\rangle$ or $|c'\rangle$. This point is alluded to in earlier work [13] but without any suggestion of how maximum entanglement might arise. This is then developed into a kind of "welcher-Weg" [15] thought experiment. But Eq. (11) would not "collapse... so that $\psi_{ent} = 0$". As before, it would collapse to either $|P_{Rx}\uparrow\rangle\,|P_{Pl}\uparrow\rangle\,|P_{O}\uparrow\rangle$ or $|P_{Rx}\downarrow\rangle\,|P_{Pl}\downarrow\rangle\,|P_{O}\downarrow\rangle$ depending on the result of a measurement capable of resolving the up or down state of any of P_{Rx}, P_{Pl}, or P_{O}. Once again, there has been a redefinition of terms: $|P_{Rx}\uparrow\rangle$ (for example) is not the state of a remedy prover experiencing symptoms but now represents all provers on the remedy who show symptoms. Milgrom has again confused occupancy of a state with the state itself.

In summary, Milgrom seems to have copied out a few equations from articles, textbooks and popularizations of quantum physics, assigned arbitrary and shifting properties to the entities within them, and then claimed to have a model/analogy/metaphor for homeopathy. The more seriously the metaphor is taken, the less sense it makes. It would be simpler to set up something called "Weak Number Theory" in which $2+2$ doesn't have to be four, and he can pretend to prove whatever he likes with that.

The author acknowledges fruitful discussions with Philippe Leick.

References

1. H. Walach. J. Alt. Comp. Med. **11**, 549 (2005)
2. H. Atmanspacher, H. Römer, H. Walach. Found. Phys. **32**, 379 (2002)
3. H. Walach. Forsch. Komplementmed. **10**, 192 (2003)
4. P. Leick. Skeptiker **3/2006**, 92 (2006)
5. P. Leick. Homeopathy **97**, 50 (2008)
6. H. M. Wiseman, J. Eisert. arXiv.org e-Print archive **arXiv:075.1232** [physics.gen-ph] (2007)
7. D. M. Greenberger, M. A. Horne, A. Shimony, A. Zeilinger. Am. J. Phys. **58**, 1131 (1990)
8. L. R. Milgrom. Evidence-based Complementary and Alternative Medicine **4**, 7 (2007)
9. M. Frass, C. Dielacher, M. Linkesch, C. Endler, I. Muchitsch, E. Schuster, et al. Chest **127**, 936 (2005)
10. Orac. Homeopathy in the - cringe - ICU, *http://scienceblogs.com/insolence/2007/07/homeopathy_in_thecringeicu_1.php* (02.07.2007, accessed 12.01.2007)
11. L. R. Milgrom. J. Alt. Comp. Med. **11**, 831 (2005)
12. A. Aspect, P. Grangier, G. Roger. Phys. Rev. Lett. **49**, 91 (1982)

13. L. R. Milgrom. Homeopathy **92**, 152 (2003)

14. L. R. Milgrom. Forsch. Komplementmed. **12**, 206 (2005)

15. M. O. Scully, B.-G. Englert, H. Walther. Nature **351**, 111 (1991)