EDITORIAL

May the spin of a chemical element affect the behavior?

The effect of lithium salts in the treatment of psychiatric, mainly maniodepresive disease has been known for tens of years (https://en.wikipedia.org/wiki/Lithium_(medication)). Nevertheless, its precise mechanism of action is poorly understood (Jacobsson *et al.* 2017, https://psychscenehub.com/psychinsights/lithium-mechanism-action-synopsis-visual-guide/). The toxicity of lithium is manageable however, needs to be carefully evaluated (Wen *et al.* 2019).

In the 1986 paper „Aberrant parenting and delayed offspring in rats exposed to lithium" (Sechzer *et al.* 1986), the authors seemingly opened a Pandora's box. Briefly, the authors used nonradioactive isotopes of lithium (Li-6 and Li-7) to treat 3 months old female rats prior to gestation, during gestation and lactation. We will focus on maternal behavior. The rats were divided into four groups: group I – control, group II – treatment with Li-N ("natural" lithium which is 93% Li-7 and 7% Li-6), group III - treatment with Li-7 and group IV – treatment with Li-6. Part of their results are shown in Table 1.

Tab. 1. Effect of different Li isotopes on the postpartum behavior. The table is partially copying the results from the original paper (Sechzer *et al.* 1986).

Behavior	Control	Li-N	Li-7	Li-6
Nest building	average	absent	absent	excessive
Nursing	average	infrequent/short duration	infrequent/short duration	very frequent/ long duration
Grooming of pups	average	infrequent	infrequent	excessive
Retrieval of pups	average	infrequent	infrequent	excessive
Reaching for food	average	infrequent	infrequent	excessive
State of alertness	average	low	low	very high

These results are qualitative. Here one can see that the maternal behavior is practically the "opposite" after the treatment of Li-7 versus Li-6. It should be noted that Li-N contains up to 93% of Li-7 so the data obtained with Li-N are the same as with Li-7. We will try to explain this data. Lithium consists of two stable isotopes Li-6 and Li-7. Li-6 consists of three protons and three neutrons, Li-7 has one neutron more i.e., four. The chemical properties of both isotopes are undistinguishable. The difference is in the nucleus – a single neutron. However, there is one quantum mechanical property which does not exist in classical chemistry and physics: the spin. The nuclear spin of Li-6 is 1, the nuclear spin of Li-7 is 3/2. From this point of view Li-6 is a boson, Li-7 is a fermion.

The magnetic field effects in biology as „the radical pair mechanism" has been widely studied (for review see Zadeh-Haghighi &Simon, 2022). We are not going in detail here. Our attempt is to suggest other possible explanation which deeply involves a pure quantum mechanical feature – the spin.

Pawlowski and Zielenkiewicz (2013) showed that the Casimir effect (Casimir 1948) may be a universal force which organizes the bilayer structure of (cell) membranes. The model was

proposed on the Casimir effect in dielectrics. It explains why the layers of a lipid membrane slide one past other rather than penetrate each other. In their model the authors clearly and nicely showed the Casimir force is a universal force that organizes "tensegrity structure" the biological membrane. Their model has been confirmed by another physicist (Bordag 2020). Casimir force "is the "quantum trap" preventing membrane leaflet interdigitation and collapse as well as maintaining a significant gap between leaflets. This leaves the planar molecules in freedom to move" (Pawlowski & Zielenkiewicz, 2013).

The Dirac (spin - 1/2) and Maxwell (spin – 1) fields are spinor fields. It is possible to use a spinor formalism to describe the Casimir effect for the Dirac and Maxwell fields in a unified way. Moreover, this unification can be used for a generalization which is applicable for confined higher spin fields (Stokes & Bennet 2015a). The authors prepared a theoretical basis showing that the solution for the fermionic field is different from the solution for the bosonic field. Under periodic boundary conditions, roughly speaking between two plates, the fermionic field solutions are aperiodic in contrast to periodic solutions of the bosonic field (Stokes &Bennet 2015b). This may have far reaching consequences for the different action of Li-6 (boson) and Li-7 (fermion). Considering a quasi-equal concentration of lithium ions on both sides of the (cellular) membrane and considering the Casimir force as organizing the tensegrity structure of cellular (and other intracellular) membranes, the bosonic field created by Li-6 can have an "overstabilising" effect on the membranes. In other words, this phenomenon can "enhance" the membrane stability. On the other hand, the fermionic field "reaches" beyond the membrane boundary and finally destabilizes the membrane. It is tempting to associate this hypothetical highly abstract physical approach with the biological postpartum female rat behavior. Nevertheless, looking at the effects of Li-6 (boson) with a "positively exaggerated" postpartum instinct and comparing the effects of Li-7 (fermion) with a "destructive" postpartum activity (Table 1), this explanation sounds plausible. The "boson-fermion demixing" of lithium atoms (Li-6 and Li-7) in a pancake trap, i.e. full demixing can be reached in the Li-6 – Li-7 mixture (Akdeniz *et al.* 2004). However, this is a theoretical prediction and in „biology free" conditions. The "destabilizing" effect of Li-N treatment (Li-N which consists of 93% Li-7) on maternal behavior has been confirmed by Peredery *et al.* (1992). Female rats before parturitions, treated with Li-N, showed complete absence of maternal behavior. Further analysis of their brains showed considerable damage of their brains (three types of cytoarchitectural damage: cystic lesions, intensified staining of neuronal fragments, gliosis) in the thalamocingulate system.

In addition, in different isotopes of Xenon Xe-132 (spin 0), Xe-134 (spin 0) (bosons) and Xe-129 (spin ½), Xe-131 (spin 3/2) (fermions) the nuclear spin attenuates the anesthetic potency in mice (Li *et al.* 2018). Bosonic xenon isotopes have a higher anesthetic potency than fermionic isotopes, and polarizability cannot account for the difference. In contrast to lithium isotopes the four isotopes have negligible difference in atomic mass; the explanation of the different anesthetic potency among them may be in the spin of their atomic nuclei. It should be noted that the mechanism by which general anesthetics cause reversible loss of consciousness, are unknown (Hameroff. 2006). Here, the "overstabilising" effect of the boson field (Xe-132 and Xe-134) on the cellular membrane hypothetically stabilizes the membrane during the "anesthetic" effect of xenon per se.

Obviously, research in this area is not at all simple and valid results cannot be expected in the near future. On the other hand, they can refute the repeated thesis that the molecule is the same when introducing new generics.

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