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Abstract: Experimental data on exposure of rodents to 900 MHz microwaves show that exposure impacts body mass index and food intake. French statistics show that the Body Mass Index (BMI) of the French population increased by about 3% after the introduction of GSM. The possibility that these observations are causally related and that the increase of the BMI of the French population may be due to the onset of GSM networks is investigated.

Introduction:

According to French statistics the average body mass index of French people increased by about 2.9% for men and 3.6% for women between a survey in 1991/1992 and the next survey in 2002/2003, whilst it had been relatively constant for men and had increased by about 0.9% for women between the surveys of 1980/1981 and 1991/1992. This increase is often attributed to the growth of the fast-food market. In this paper the alternative hypothesis that the increase would be due to the onset of GSM networks is investigated. The available experimental data on animal models is described, including variations in experimental results. The possible link between GSM onset and increase of body mass index in exposed populations is discussed based on experimental data and based on the underlying physics.

I-The experimental data.

Body mass variations of rodents under 900 MHz exposure have been extensively studied. Table 1 summarizes these results.

The initial observation was that female mice subject to 900 MHz modulated irradiation had their weight increased by 6% during a 280 day exposure period (Sommer & al 2004). This phenomenon will be called hereafter "GSM weight increase". Later experiments confirmed this result and clarified its applicability. The weight increase was frequency-dependent, since it took place at 900 MHz but not at 1800 MHz and since at 383 MHz it was limited in magnitude and duration (Lerchl & al 2008). In hamsters at an unspecified temperature GSM weight increase took place at 0.08 W/kg but not at the higher Specific Absorption Rate (SAR) of 0.4 W/kg nor at the near thermal SAR of 4 W/kg (Lerchl 2009). In a first generation born under exposed conditions there was a 5% (p=0.1 two tailed) trend to weight increase effect on male rats and a 2% non-significant increase on female rats at 0.4 W/kg (Bornhausen & al 2007) but in the second generation born under exposure there was a significant weight decrease for females. The GSM weight increase was observed on young male rats at 1 V/m (Appendix, based on Pelletier & al 2011). The GSM weight increase was accompanied by an increased food intake (Lerchl 2009 and Pelletier & al 2011, 2013). A +3% GSM weight increase was observed at 0.25 W/kg for 1h/day exposure on female mice: the 3% increase on Figure 2-A of (Utteridge & al 2002) is expected to be significant because it is averaged on 120 mice, as compared to 13 rats in (Pelletier & al 2013). This +3% GSM weight increase appeared after 5 months of exposure and lasted until about 14 month of exposure after which it disappeared. It was present in wild-type female mice but not in transgenic Eμ-Pim1 female mice.

Since exposure values below 1 V/m were not tried out, it is not yet known what a possible threshold may be for the effect.

Thus “GSM weight increase” is experimentally proven as a frequency-dependent long term effect in rodents at 900 MHz, down to 1 V/m.

Year	!Reference	Affiliation	Animals	generation	Timing	temperature	frequency	Modulation	W/kg	W/m2	V/m	weight	Food intake	Tail temperature
2004	Sommer&al	Univ. Bremen	Female mice		24h/d 280d	21°C	900 MHz	GSM-like (station base+mobile)	**0.4**	24	95	+6%		
2008	Lerchl & al	Jacobs University Bremen	Male Hamsters		24h/d 60d	14°C ?	383 MHz	Tetra	**0.08**	1,35 (c)	22 (c)	0% [3% (b)]		
							900 MHz	GSM	**0.08**			+6%		
							1800 MHz	GSM	**0.08**			0%		
2009 ?	Lerchl						900 MHz	GSM	**0.08**	1.35	22	+6%	+4%	↘NS
									0.4	7	50	NS	↗NS	↘NS
									4	70	160	-4%	-8%	+0,5°
2007	Bornhausen & al	Ludwig Maximilians Univ. Munchen	Male rats	F1	24h/d 84d ap.n.	20°C	900 MHz	GSM	**0.4**	28	102	+5% (p=0.1)		
			Female Rats									+2%NS		
			Male rats	F2								0%NS		
			Female Rats									-5%		
2011/ 2013	Pelletier & al	Lab. Peritox (INERIS)	Male Rats		23,5h/d, 35d	24°C	900 MHz	Cw			**1**	+5%	+15% NS (a)	-0.1° NS
						31°C	900 MHz	Cw			**1**		+300% (a)	-1°
2002	Utteridge & al	(Australia)	Female mice		1h/d 5d/w 2 years	21°C	898.4 MHz	repeated GSM pulses	**0.25**	15 (d)	75 (d)	+3%(e)		
			transgenic fem.mice									0%		

Table 1: Experimental data on body weight and food intake variations in rodents exposed to microwave frequencies. Some values are approximate, being disclosed only in the form of graphics in the original publications. NS: non-significant. (a): from 12:00 to 18:00 only. (b): transient increase of 3% but no long-term increase.(c) approximate values deduced from (Hansen & al). (d) approximate values based on the same ratios as in (Sommer & al). (e) from 6 to 14 months of exposure corresponding to 8 to 16 months of life.

<u>II- Variations in experimental data.</u>

The reason for which in (Lerchl 2009) the GSM weight increase is inversed at 4 W/kg and essentially canceled at 0.4 W/kg is unclear at this stage. It could be related to general ill health of the animals at a rather strong exposure level, or to a more fundamental effect which may be explainable under a suitable quantum model of the interaction. Since the value of 0.4 W/kg is intermediate between the values for which GSM weight increase exists (0.08 W/kg) and is reversed (4 W/kg) in (Lerchl 2009), it is generally likely to be particularly sensitive to experimental conditions.

This competition between the weight increase effect which dominates at 0.08 W/kg and the weight decrease at 4 W/kg may also explain why in (Bornhausen & al 2007) at 0.4 W/kg a weight decrease effect was observed on female rats of the second generation (F2). However, one cannot exclude the alternative possibility that under continuous exposure the effect may be generation-dependent, as a result of some adaptive mechanism which is not yet understood.

The experimental temperature in (Lerchl 2009) was unspecified and probably “following the outside temperature” as in (Lerchl & al 2008), which is likely less than 21° and may mean a typical temperature of 14°. Therefore the difference in temperature is one of the possible explanations for which the weight increase effect was not observed at 0.4 W/kg in (Lerchl 2009) whilst it was observed at 0.4 W/kg at 21°C in (Sommer & al 2004) and at 20°C (Bornhausen & al 2007).

The disappearance of the GSM weight increase in aged mice after 16 weeks of exposure in (Utteridge & al 2002) is not incompatible with the other observations as this is the sole case in which the experiment lasted for so long.

Thus the GSM weight increase seems to disappear in old female animals. There is no comparable long-term data for males.

The lack of GSM weight increase in transgenic heterozygous Eμ-Pim1 mice is an indication that the Pim1 protein may somehow interfere with the GSM weight increase, and more generally that despite the wide inter-species range of GSM weight increase, some subtle intra-species genetic differences may affect it.

In the two experiments carried out on mice (Sommer & al 2004, Utteridge & al 2002) the GSM weight increase appeared after about 28 weeks of exposure, corresponding to an unspecified age which was probably about 34 weeks in both cases (mice had reached the laboratory at age 5-6 weeks). In the experiments on rats the GSM weight increase appeared much earlier: 2 weeks of exposure corresponding to about 5 weeks age in (Pelletier & al 2011), and also very early but only as a non-significant trend (due to high standard deviation) in (Bornhausen & al 2007). Thus the age-dependency of the GSM weight increase seems to be dependent on the species.

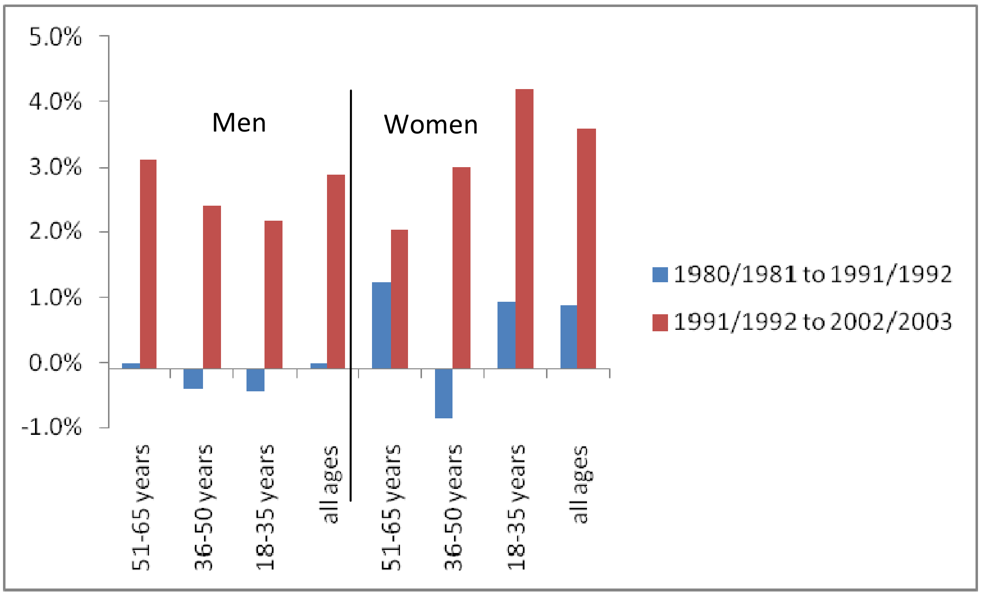
III-Discussion based on experimental data.

The observation of GSM weight increase in hamsters, mice and rats suggests that it affects at least all rodents and possibly all mammals, including humans, down to at least 1 V/m. Thus at least the proportion of the human population which is exposed to GSM at more than 1 V/m should be subject to the GSM weight increase effect.

Observed GSM weight increase is 5% to 6% independent of exposure power between 1 V/m and 100 V/m. Therefore the underlying biological effect is expected to yield a binary decision yielding a roughly 5% weight increase above a threshold. This threshold is lower than 1 V/m but is still unknown. Biological effects below 0.06 V/m have been observed in different contexts (Lauer 2013, Cherry 2002) so that the possibility that the threshold for the GSM weight increase effect is below 0.06 V/m cannot be excluded. Since this is below exposure values to which most of the human population is exposed to GSM downlink in France, the GSM weight increase effect may apply to most the French population based on exposure to downlink GSM.

Observed GSM weight increase was lower (3% instead of more than 5%) but still present at 75 V/m when exposure lasted only 1 hour daily. The effects of a temporary exposure seem to be damped over time with a timescale of the order of a day, but they do remain significant over time despite the fact that the daily exposure time is low. Therefore, temporary exposure of GSM users to uplink GSM during calls (and probably exposure of their neighborhood exposed temporarily to more than 1 V/m during the call) may also contribute to the GSM weight increase affecting the French population. Since in 2002 the penetration rate of GSM on the French market was more than 60% (Renault 2007), the share of GSM weight increase due to exposure during calls may have been significant.

The average weight of French men and women increased by about 2.9% (men) and 3.6% (women) between the 1991/1992 and the 2002/2003 surveys of the INSEE (Saint Pol 2007) roughly corresponding to the first 11 years of GSM (which started operating in 1992) whilst it had been previously stable (0.0%,men) or slowly increasing (0.9%, women) between the 1980/1981 survey and the 1991/1992 survey (see Graph 1). The magnitude of the weight increase is comparable to the magnitude of the observed GSM weight increase in rodents. Its timing corresponds to the onset of 900 MHz exposure, which is the only one for which a long term effect exists (Lerchl & al 2008). The effect was of lesser magnitude on women aged more than 50, which is comparable to the disappearance of the GSM weight increase in female mice after about two thirds of their lifespan in (Utteridge & al 2002). Thus on a strictly factual basis, it is likely that the increase in the body mass index of the French population between the surveys of 1991/1992 and 2002/2003 is due to the onset of GSM. More specifically, it is likely to result from a mix of the effects of permanent exposure to downlink GSM from base stations, and temporary exposures of GSM users and their neighborhood to uplink GSM during calls. Whether the contribution of temporary exposures is decisive or not depends on the power threshold of GSM weight increase: if the power threshold is relatively high, the contribution of temporary exposures is likely to be decisive. If the power threshold is low enough so that the majority of the population is affected base solely on exposure to downlink GSM, the contribution of temporary exposures is marginal insofar as GSM users are affected whether or not they make calls.



Graph 1: increase of Body Mass Index in France between successive surveys.

<u>IV-Discussion based on physics.</u>

In view of the experimental data, an essential question is whether the power threshold for the GSM weight increase effect can be low enough so that the majority of the French population is affected due to exposure to downlink GSM, and. whether such low power threshold could be "explainable", even in the case of a 1 V/m exposure.

It was proposed in (Lauer 2013) that at least some non-thermal mechanisms of interaction of electromagnetic waves with biological systems are based on stimulated transitions between different conformations of proteins or other biological systems. A practical case of non-thermal transition between different conformations of a protein, stimulated by a microwave electromagnetic wave, is described in (Bohr 2000), although at a high power. The near instantaneous nature of the transition in (Bohr 2000) suggests that the stimulated transition mechanism described in (Lauer 2013) may be implied. Further, the effect of the transition in (Bohr 2000) is to quickly bring the protein to its thermal equilibrium state instead of the protein staying in a non-equilibrium state due to slow kinetics, as was suggested in (Lauer 2013) sections 1 to 4 – although in (Lauer 2013) only the case of a pulsed wave was considered.

In a stimulated transition, the artificial electromagnetic wave affects a transition which is otherwise stimulated by the thermal background. If stimulation by the thermal background is negligible and the transition is not of biological interest absent the electromagnetic wave, then the power threshold above which the electromagnetic wave causes an effect may be relatively high as is the case for example in (Panagopoulos & al 2010) as discussed in (Lauer 2013). But where stimulation of the transition by the thermal background is part of the natural functioning of an affected biological sub-system, as is the case for example for recognition of the cognate antigen in (Lauer 2014), an artificial electromagnetic wave can disturb the normal functioning of the affected sub-system (assuming the frequency and bandwidth are optimized) as soon as its power exceeds the power of the thermal background on a specific frequency range corresponding to the excitation frequencies of transitions between the two conformations. For GSM weight increase, this frequency range would be roughly 500 to 1500 MHz, based on the frequency dependency observed in (Lerchl & al 2007). Even considering a probably over-estimated frequency range of 0 to 3 GHz, the power of the thermal background within this frequency range is only 8 nW/m2 (about 2 mV/m) as calculated in (Lauer 2014).

In the recognition of the cognate antigen as described in (Lauer 2014), for a specific T lymphocyte and Antigen Presenting Cell (APC) the final outcome is binary, i.e. the T lymphocyte attacks the APC or it does not. Therefore, there is a threshold, which can be anywhere above the minimum theoretical level, above which the attack of the APC by the T lymphocyte will be inhibited. The magnitude of the GSM weight increase is roughly 5% at 1 V/m, 22

V/m and 100 V/m, i.e. it is substantially independent of power. This shows that the affected biological sub-system in GSM weight increase yields a binary decision similar to the case of antigen recognition, and that there is a power threshold above which the effect takes place and below which it does not take place. This power threshold can be anywhere from the theoretical minimum of 2 mV/m to the value of 1 V/m for which GSM weight increase was observed.

The above considerations confirm that the observed effect at 1 V/m is fully explainable within accepted concepts of physics. Since based on theory the power threshold for the effect is somewhere between 0.002 V/m and 1 V/m and since the lower bound is well below the average exposure of the French population, it is possible that a majority of the population was affected by GSM weight increase, on the basis of exposure to downlink GSM from base stations.

V-Conclusions.

Based on the physics of stimulated transitions, on comparable existing power ranges, on measured effects below 1 V/m, on the fact that all rodents, and thus possibly all mammals, seem to be affected, and on observes effects of temporary exposures, it is likely that a majority of the population was affected by GSM weight increase and that the roughly 3% increase of the Body Mass Index of the French population between the 1991/1992 survey and the 2002/2003 surveys was thus due to the onset of GSM (which started operating in 1992). This reasoning is summarized on Figure 1. On the other hand one cannot entirely exclude the possibility of the time coincidence between onset of GSM and BMI increase of the French population being due to chance. Yet even in such case, a GSM weight increase effect is likely to exist at least in persons subject to higher than 1 V/m downlink GSM exposure levels and in sufficiently heavy users of GSM – this could be wrong only if results obtained on several animal species are not applicable to humans in the present case.

It should be feasible to confirm the extent of the GSM weight increase and its applicability to species other than rodents by experimenting very low exposure conditions and short daily exposure times on several appropriate animal models. Confirmation at sufficiently low exposure level and/or short daily exposure durations and for sufficiently diverse animal models would also confirm the present analysis as to the probable cause of the observed BMI increase in humans. Experimentation on humans would ideally be preferable but poses practical difficulties.

The underlying physics and the possibly low power threshold also have implications on experimental conditions for such investigation. Complex interferences between background environmental exposure and experimental exposure levels cannot be excluded. Background exposure of the control group may also affect experimental results. In order to improve the reliability of experimental results it would thus be of interest to tightly control the electromagnetic background noise, particularly at the GSM frequencies around 900 MHz. If this is done by using Faraday cages, possible interferences with the immune system as mentioned in (Lauer 2014) should preferably be avoided by breeding the animals inside the Faraday cage, including at least a parental generation. Since the possibility that GSM weight increase may be generation-dependent under continuous exposure cannot be excluded, it would even be wise to breed rats inside Faraday cages for several generations. Also, increased bandwidth may result in a lower power threshold because more transitions (corresponding to different transition frequencies) are simultaneously stimulated. In an experimentation targeted to defining a threshold for the GSM weight increase effect, it would thus be essential to use a realistic simulation of exposure to downlink GSM emission, including a sufficiently large signal bandwidth.

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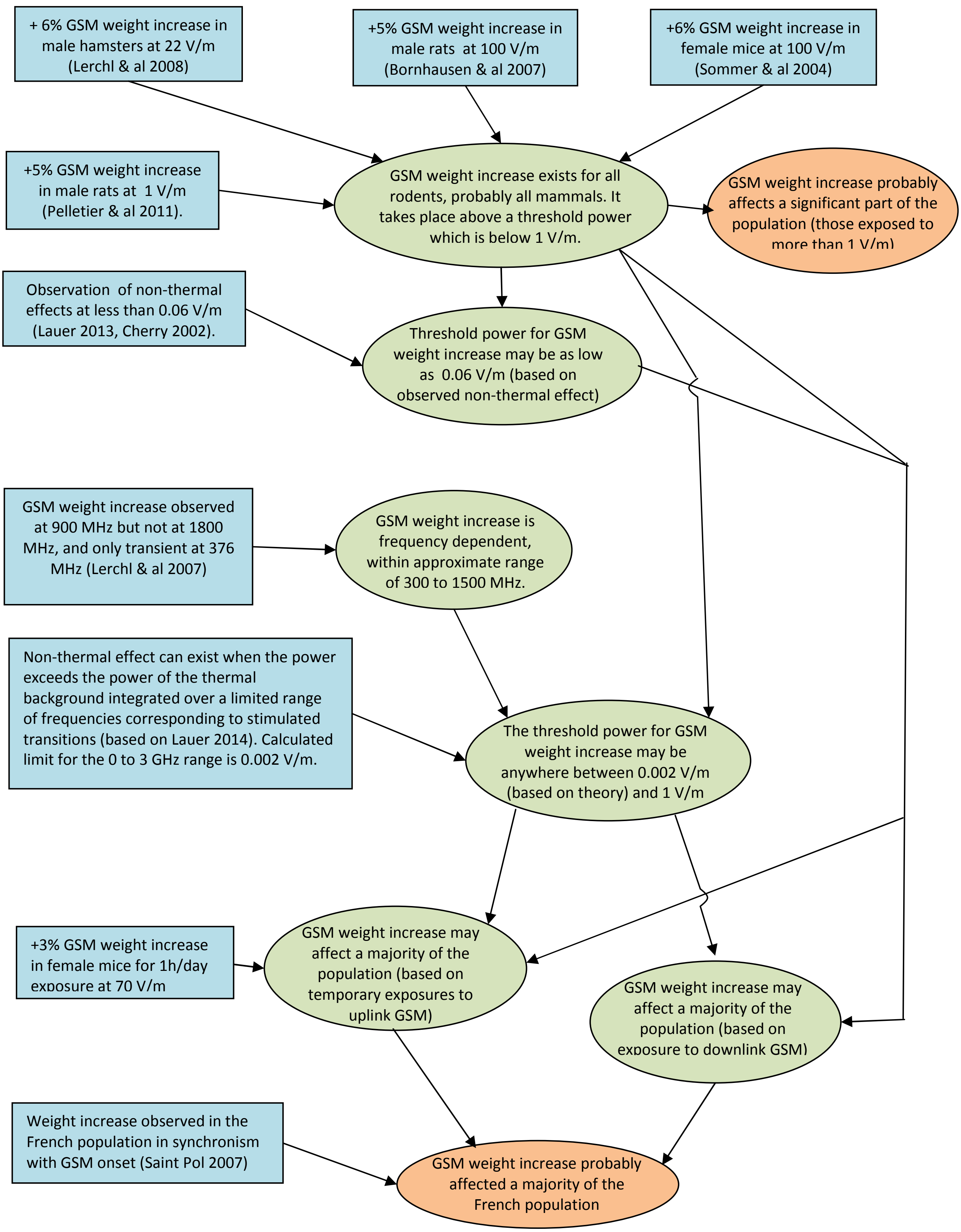

Figure 1 : Summary of the reasonings and conclusions.

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Appendix : Weight increase in (Pelletier & al 2011).

In (Pelletier & al 2011) the weight increase curve at 1 V/m is published, including the graphic indication of the standard deviation of the means. Numerical values in Table A1 are approximations taken from the graphics.

Days of exposure	D1	D15	D25
Weight, control group, grams	58	160	244
Weight, exposed group, grams	61	171	255
Standard Deviation of the Means , in each group, grams	1.5	2.8	4.5
Weight difference Exposed-Control, grams	3.0	11.1	11.1
Percentage difference	5%	7%	5%
z	1.4	2.8	1.7
p two-tailed	0.157	0.005	0.084
p one-tailed (probability of the difference between groups being larger than observed)	0.079	0.002	0.042
Expected Standard Deviation of the Means, in each group, grams		5.5	5.5
F		4.00	1.49
P1 (probability of the standard deviation being less than observed, in control group, with N=11)		0.02	0.27
P2 (probability of the standard deviation being less than observed, in exposed group, with N=13)		0.01	0.25
Pt (probability of the standard deviation being less than observed, in both groups)		0.0002	0.068

The results show a significant excess of weight of about 5% to 7% of the exposed group over the sham exposed group at days 15 and 25, which may correspond to a GSM weight increase (it is permissible to use one-tailed p-values, because a GSM weight increase is expected rather than a decrease. On day 25 it is also permissible because the existence of the GSM weight increase is confirmed on day 15 based on the two-tailed p-value). However the fact that at the first day of exposure the exposed group was already 5% heavier than the non-exposed group sheds doubt on this result since the relative weight of each group increased equally between day 1 and day 25. It is thus necessary to answer the following question: is the weight difference between the exposed and non-exposed groups due to the original weight difference, or not ? If not, the only remaining answer is that it is attributable to the GSM weight increase.

If the weight difference between the groups is due to the original 5% weight difference, then the standard deviation in each group and the weight difference between groups are expected to increase at the same rate. This yields an Expected Standard Deviation of the Means at days 15 and 25 for each group, based on the standard deviation at day 1 and on the weight difference between control and exposed groups. A F-number can thus be calculated for each of the days 15 and 25, which is the expected variance divided by the observed variance. The probability P1 [resp. P2] of the standard deviation being less than observed in the control [resp.exposed] group is calculated from an F-distribution table. The probability Pt of the standard deviation being less than observed in both groups is the product P1*P2. The deviation of the observed variance from the expected variance is significant at day 15 and near significant (Pt=0.068) at day 25. Thus the standard deviation in each group and the difference between groups did not increase at the same rate from day 1 to day 15, and the weight difference between the groups at day 15 is not due to the original 5% weight difference between the groups at day 1. Since the weight difference between groups at day 15 is unrelated to the original weight difference between groups, the weight difference between groups at day 25 is also expected to be unrelated to the original difference between groups. Since these weight differences are not due to the original 5% difference between the groups, they are due to the GSM weight increase. Thus the observation of GSM weight increase in (Pelletier & al 2011) is significant.