

August 30th, 2018

Ms. Carolyn McNally,
Secretary,
NSW Planning & Environment,
GPO Box 39,
Sydney NSW 2001

Dear Secretary,

RE: MP08 0252 Flyers Creek Wind Farm (Modification 4)

I am opposed to the proposed Modification 4 of the Flyers Creek Wind Farm.

Introduction:

I point out that the time allowed for public comment about Modification 4 of the FCWF has been completely inadequate. The proponent has had many months to assemble the prodigious quantity of material in its application to NSW DoPE; as usual the public have had 2 weeks only to digest **941 pages** and contribute a coherent submission.

On many occasions I, and others, have complained about this patent unfairness; unfortunately to no effect.

I am on record as opposing this industrial wind turbine development from its inception have made submissions to this effect since the original EIS was put on public display.

My original objections remain and can be found in my submissions to the original application, the 2nd and 3rd modifications and my submission to the Planning and Assessment Commission.

My comments at the time included:

- The inappropriate siting of the FCWF in a closely settled rural area where there will be a significant impact on many people;
- The inadequacy of the setback conditions of wind turbines from nearby non-host residences;
- The inadequacies of noise modelling, for example using units of dB(A) instead of the more meaningful dB(C) or better still unweighted measurements;

- The construction of such large industrial complexes with significant health impacts on hosts and non-hosts alike from infrasound and low frequency sound. Not enough research has been done to discount the possibilities that harm will be done to the local population;
- The visual impact;
- The negative impact on real estate prices;
- The inadequate provisions for decommissioning;
- The disruption and fracturing of community.

Comments – Modification 4 of the FCWF:

The proposed modification involves:

- an increase to the wind turbine envelope (including a 10 m increase in tip height); and
- inclusion of a 132 kV transmission line and switching station to enable the Project to connect to the electrical grid.

Rather than re-iterate the information in my previous submissions I provide the following comments:

Justification of the benefits attributed to FCWF by the proponent, Infigen:

- (1) Infigen: In full operation, the Project would generate approximately 430 Gigawatt hours ("GWh) of electricity per year - sufficient for the average consumption of approximately 58,000 homes.

Comment: 58,000 homes will only get electricity from wind power when the wind is actually blowing. In the absence of any electricity storage these homes will be supplied power from a conventional source (coal, gas mainly). These base-load producers of electricity need to be on "stand by" at all times, at a significant cost.

- (2) Infigen: It would assist in replacing the 1,000 megawatt (MW) shortfall identified by the Australian Energy Market Operator as being required to supplement the lost generation capacity which will result from the planned closure of the Liddell Power Station in 2022.

Comment: In April 2018 the Liddell Power Station was estimated to have 1680 MW operating capacity (down from its original 2000). Modification 4 of the FCWF claims an operating capacity of 159.6MW (38x4.2) which is 9.5% of Liddell's current operating capacity. FCWF can only claim a very minor role in making up for Liddell's closure *particularly* as FCWF will be supplying intermittent wind power. Wind turbines, because of the vagaries of too much or too little wind, can only claim to operate at about 30% capacity (and sometimes much less).

To claim that a wind turbine generating intermittent electricity can compensate in any effective way for a power station producing base load electricity is a distortion of the reality of electricity production and distribution.

- (3) Infigen: It would contribute to the State and Federal Governments' target of providing 33,000 GWh from renewable sources by 2020.

Comment: FCWF is projected by Infigen to produce 430 GWh per year when operational. That is a miniscule 1.3% of the 33,000 GWh from renewable sources that the various State and Federal Governments are targeting; hardly a serious justification.

- (4) Infigen: It would contribute to the NSW Government's target of reducing greenhouse gas emissions by 60% by the year 2050.

Comment: The NSW target is not quantified; 60% of what level of greenhouse gas? But the same comment as above would apply. FCWF will be contributing a very small amount to the target whatever it is.

- (5) Infigen: It will contribute to inter-generational equity by reducing greenhouse gas emissions and reducing consumption of finite fossil fuel resources.

Comment: This is a fatuous generalisation which is doubtless meant to give us feelings of virtuous self-congratulation, but in fact is a complete lie. The arguments for or against the possibility of reducing greenhouse gas emissions, or whether it is even desirable, continue to be publicly debated. The spectre of "global warming" and "climate change" is produced to ensure the knee-jerk reaction that any project (such as wind power) purporting to reduce these global phenomena must be supported at all costs. This is not the platform to argue the risibility of the current climate change debate but given that any climate change is unlikely to be affected by FCWF Modification 4, the claim regarding inter-generational equity is clutching at straws and cannot be taken seriously.

The claim that FCWF Mod 4 will reduce the consumption of finite fossil fuel resources is also laughable. There has been well documented research following the life cycle of wind turbines, their construction, establishment, operation and eventual decommissioning (if decommissioning ever occurs -abandonment would be more apt). It is generally concluded that more greenhouse gases are emitted (and more fossil fuel resources used) over the lifetime of the WT than is "saved" by the production of electricity from "free wind".

- (6) Infigen: It will provide full time employment for a peak of 140 people during construction and up to 6 to 10 ongoing regional jobs during its operational life.

Comment: This is hardly a justification for a modification to the FCWF. Experience has shown that many of the people employed during construction are contractors who do not live in the district and who do not particularly contribute to the district economy. 6-10 employees during the operational phase (often also contractors from outside) have in the past been quoted as less. In any case on a region-wide basis they are not a significant percentage of the district work force.

- (7) Infigen: It will result in a direct injection of approximately \$1 million per annum to the local community through payments to landholders, permanent staff and community fund contributions.

Comment: From the sale of electricity and the receipt of subsidies (via the LRECs at least) Infigen will be receiving the better part of \$1,000,000 per turbine per year. The direct injection described above into the community is a mere 2.6% of estimated income which, even making allowances for operational expenses and return on investment, is paltry.

Additional Comments:

- (1) The original proposal for the FCWF indicated significant impacts on the local community. The initial EIS noise modelling used a GE 2.5MW turbine. The current proposal intends to use 4.2MW turbines. This is a 68% increase in turbine size. Despite all the modelling done there is no obscuring the fact that there will be a great deal more noise, vibration, bird and bat destruction, health effects, visual pollution and general disruption to community welfare.

Infigen argues that, because several wind turbines have been removed from the wind farm (46 to 28) overall, there will be no consequences to enlarging the individual wind turbine size. This is a self-serving argument. If, for instance, a non-host is living adjacent a 4.2MW turbine he is individually going to be more affected than if he was living next to a 2.5MW turbine.

- (2) Cumulative effects have been consistently neglected but are increasingly important as mining and other developments come into play. Newcrest's Cadia East mine is close by and it already impacts residents, particularly the blasting (and seismic activity). A major gas pipeline runs through many of the wind turbine effected properties – noise and vibrations have a history of effecting these adversely. Larger wind turbines will exacerbate this situation.

Has anyone addressed these issues?

- (3) Infigen seeks to enlarge the wind turbine size to increase the profitability of the FCWF. No doubt the argument will be proffered that it is good business to do so. This will

increase its sale of LRECs (the cost to the energy retailers being passed onto the electricity consumers) and consequently its income.

Is it the role of Government (here the NSW DoPE) to facilitate the profitability of a private energy company at the expense of the Australian citizens it so adversely effects?

It is not the role of NSW Planning & Environment to rubber-stamp any application for development that is submitted to it. Surely its (your) primary function is to work for the benefit of the people whose lives will be affected adversely by such developments as the Flyers Creek Wind Farm.

I therefore urge you to carefully consider the submissions that will come to you in opposition to this current Infigen proposal. There is a reason that many people have energetically opposed the FCWF and dedicated many years (now) of their lives to putting their arguments forward. It is regrettable that so little notice has been taken of their situation. They deserve better.

It would be a validation of your role and your influence if you were to refuse to approve Modification 4 of the FCWF. I commend this action to you in the strongest terms.

Yours faithfully,

A handwritten signature in black ink, appearing to read 'C. Watts', with a long horizontal flourish extending to the right.

Dr. Colleen J Watts OAM



Planning Assessment Commission Meeting

Flyers Creek Wind Farm

Blayney Shire

Wednesday 12th February, 2014

SUBMISSION

Today I ask you to REFUSE approval for the construction of the Flyers Creek Wind Farm, an industrial behemoth which will surely blight our landscape and the lives of the many people who will live within and close by to it. I speak both as a resident of Blayney Shire and as an environmental scientist who has the training and experience to be able to analytically and objectively assess this project.

I find nothing of merit in this project and it fails spectacularly on all fronts: economic, environmental, noise and adverse health implications, and visual pollution. It ignores democratic rights, landowner rights, human rights, the rights of residents who want nothing but the “quiet enjoyment” of their homes and farms.

Industrial wind turbines CANNOT fulfill their purported function, that of reducing carbon dioxide in the atmosphere and thereby making a supposed difference to climate change. The life cycle of a wind turbine, the intermittent nature of its energy production requiring base load electricity generation backup and other negative impacts means that it effectively saves NO carbon dioxide emissions at all.

What sort of a travesty is that? Who is the Government backing when it continues to approve these projects? Certainly the Government has failed to listen to the people. If it was not for the subsidies available to the wind energy proponents via the Renewable Energy Certificates (valued at upwards of \$500,000 per wind turbine per year) these projects would not even get off the drawing board. Hardly a mature technology they collapse once Government support is withdrawn. The rest of the world is waking up. It is time we did too before our landscape is littered with these monstrosities.

In October 2012 my husband, Dr. Alan Watts, and I made a Supplementary Submission to the Department of Planning and Infrastructure concerning this proposed wind farm.

Of great concern was (and is) the number of NON-HOST RESIDENCES that fall within the 2 kilometres setback distance from the wind turbines. I submit a copy of the original report although I understand you have read and are familiar with all submissions to the Department.

I draw your attention particularly to Table 1 in the Appendix which lists 24 non-host residences which will have one OR MORE industrial wind turbines within a 2 kilometres radius. The worst example is one residence which would have NINE wind turbines within 2 kilometres. Imagine for a moment having nine turbines within 2 kms of your house and the impact that must have on your life and the life of your family.

I also point out Figure 1 in the Appendix. It graphically illustrates the impact of the wind turbines with a setback distance of 2 kilometres basically affecting the whole of the wind farm. I am supplying a copy for each of you to study. It is an extremely ugly diagram.

The Government published the Draft Guidelines for Wind Farms (in 2012, yet to be finalised, what is taking the time?) establishing the code of a mandatory setback distance of 2 kilometres for non-hosts, unless the non-host actually agrees.

As we all know, Flyers Creek Wind Farm is not being assessed under these Draft Guidelines. Infigen was fortunate enough to get its application in to the Department of Planning and Infrastructure prior to any mooted changes in the guidelines. They were also fortunate enough to be RETROSPECTIVELY declared critical infrastructure Minister for Planning. via a strange sleight of hand by the previous government when Ms Keneally was The Government is obviously concerned about setback distances, otherwise why bring it forward in the draft guidelines? The Government has, in an abject appeal to wind farm proponents, asked them to at least consider the 2 kilometre setback even if it isn't as yet legally enforceable. Infigen has made no such attempt with Flyers Creek. How could they? The project would instantly become untenable.

I refer you back to Figure 1 which amply demonstrates that almost all the wind farm places wind turbines within 2 kilometres of non-host residences. The Victorian and NSW Governments believe 2 kms is the minimum setback distance while Infigen obviously does not.

The Government has declared that the requirement for 2 kilometre setbacks will not be made retrospective, that is, any projects with applications before the Department of Planning prior to March 2011 will not have to abide by this. But the Government is being coy. There is nothing magic about retrospectivity. The Labor government was quite happy to make Flyers Creek critical infrastructure retrospectively and then of course there is Barangaroo.

There has been a change in the wind farm plan. Infigen has removed turbine #17 apparently because of visual impacts. I do ask therefore what about the visual impacts of the remaining 40 odd wind turbines? The Department of Planning has recommended the removal of turbine # 9 and #12 (but this will be up to you, the PAC, to endorse this).

Removal of three turbines makes very little difference to the impact of the wind turbines. There will still be 24 non-hosts residences affected. There is some reduction in the number of wind turbines that will affect some non-hosts. For instance House R089 will now have EIGHT instead of NINE turbines within two kilometres. I am sure the residents will appreciate that.

I submit to the Commissioners an amended Table 1 with the updated numbers of wind turbines within two kilometres for the 24 non-host residences.

I note that the Department of Planning has also stated that Infigen will also be required, and be given twelve months to do so, to sign contracts with three hosts and the landowner across whose farm the high voltage power lines are to be routed. If the three hosts do not re-sign this will remove wind turbines #4, #13, #14 and #16, and will also affect access roads. This will still have minimal effect on the number of non-host residences being affected by wind turbines within 2 kilometres which will be reduced by a mere two to 22. The most effected (residence R089) still will have SEVEN wind turbines.

In summary therefore, the removal of wind turbines #9, #12, #17 will result in:

Number of Non-host residences	Number of IWTs within 2 km
1	8
2	7
1	6
2	5
1	4
5	3
6	2
6	1

Note also that one of the non-host residences with two IWTs within 2 kilometres will also have the substation at about 400 metres.

Errowanbang School with the removal of IWTs #9 and #17 will still have a wind turbine (#11) at 2 kilometres. There are significant concerns about adverse health effects of wind turbine noise on children and learning, and there is ample research to support it. Even the current Minister of Education has insisted on adding DGRs specific to the needs of school children in his care. Infigen has not seen a need to safeguard our children as we and the Minister do. You also have an opportunity to safeguard our children.

Lastly, if they are concerned, HOSTS will also be affected. There will now be 25 host residences within the 2 kilometre setback distance, the worst having EIGHT wind turbines.

The number of residences falling within the 2 kilometre currently recommended setback distance is absolutely reprehensible. There can be NO justification for approving this project when so many people will be significantly affected. You can say 24 non-host

residences quickly without considering that will be 24 families whose members will include children, the elderly and the physically disadvantaged, all of whom are prone to the greatest adverse health impacts. Approval of this project will make a mockery of any concern the Department of Planning is expressing through its Draft Guidelines.

The repercussions from approval of this project will be immense and probably irreversible. There will be no going back from a bad decision by the Planning Assessment Commission. Let me be clear, approval of this project by your commission will forever destroy this rural area and for many render it unliveable.

The National Health and Medical Research Council, despite its ridiculous and risible 2010 Rapid Review, does however urge the application of the PRECAUTIONARY PRINCIPLE. That at least is wise advice.

I strongly urge you, the Commissioners, to carefully consider this proposal, to apply the precautionary principle, to adhere to the spirit of the Draft Wind Farm Guidelines and most importantly realise its human ramifications. I strongly urge you to reject the Flyers Creek Wind Farm proposal outright.

This project is without any merit and is laughably unfit for purpose and is sociably destructive beyond measure.

A handwritten signature in black ink, appearing to read 'C. Watts', with a long horizontal flourish extending to the right.

Dr. Colleen J. Watts OAM

**PROPOSED FLYERS CREEK WIND FARM
BLAYNEY SHIRE COUNCIL AREA
MP 08 0252**

Re: Infigen's application for Modification 3

SUBMISSION

TO

**NSW DEPARTMENT OF PLANNING &
ENVIRONMENT**

Dr Alan C Watts OAM

H.D.A., B.Sc., M.B. Ch.B., L.R.C.P., M.R.C.S.

Dr Colleen J Watts OAM

B.Sc.Agr.(Hons), M.Phil., PhD.

“Highfield” Carcoar 2791

June 2017

5th June 2017

Submission to:

Resource Assessments
Department of Planning & Environment
320 Pitt Street
GPO Box 39
Sydney NSW 2001

Dear Mr Davies

Re: Flyers Creek Wind Farm MP 08_0252 – Modification 3

1. **INTRODUCTION**

We refer to previous submissions we have made to the NSW Department of Planning & Environment (previously known as the NSW Department of Planning & Infrastructure) concerning the planned, and subsequently approved, Flyers Creek Wind Farm:

- | | | |
|-------|---|---------------|
| (i) | Original submission – Dr Alan Watts | December 2011 |
| (ii) | Original submission – Dr Colleen Watts | December 2011 |
| (iii) | Supplementary submission – Drs Alan & Colleen Watts | October 2012 |
| (iv) | Submission to PAC – Dr Alan Watts | February 2014 |
| (v) | Submission to PAC – Dr Colleen Watts | February 2014 |

In addition we have made several other relevant submissions to the DoPE concerning the impacts of wind farms, including:

- | | | |
|------|---|----------------|
| (i) | Submission re Draft NSW Planning Guideline Wind Farms –
Drs Alan & Colleen Watts | March 2012 |
| (ii) | Submission re Wind Energy: Assessment Policy
Drs Alan & Colleen Watts | September 2016 |

We have also made submissions to the three Federal Parliament Senate Enquiries into industrial wind turbines and their ramifications; to the NHMRC and to other State's enquiries.

This submission forms an addendum to the material listed above.

Over the past decade when there has been an attempt to regulate the wind industry we have seen a steady erosion of any protection of the community's interest, particularly but not exclusively in the area of health sequelae due to the operation of industrial wind turbines (IWT).

This has been particularly noticeable in the changes made between the 2012 Draft Guidelines and the 2016 Wind Energy Guidelines. The latter is a watered-down version full of motherhood statements

and offers no real protection to the community. For example the 2016 version has removed all discussion of setback distances and presumably relies on predictions of sound. Our previous submissions have addressed this issue in detail but there is a very real sense that the DoPE does not want to acknowledge this issue and its very real implications.

We are members of the Flyers Creek Wind Turbine Awareness group (FCWTAG). We support and endorse the group's current submission to the DoPE concerning the Flyers Creek Wind Farm Modification 3 application. The submission has made several statements of fact, and backed them up with considered and critical argument.

The Department of Planning and Environment must be aware of the significant anger, disaffection and depression that has been caused by the relentless roll-out of approvals for industrial wind farms in NSW – Flyers Creek Wind Farm is but one.

It is time that DoPE (and the PAC) started listening to community concerns, addressed the possibility that wind farms (being utterly unfit for purpose) should not be approved at all and stopped acting as an extension of the wind industry.

2. IMPACTS OF TURBINE REMOVAL

Previous IWT hosts at R014, R024 and R056 are no longer participating in the wind farm project. In so doing IWTs 4, 13, 14, 16 are to be removed from the project. This forms part of Modification 3. These three properties become non-hosts and should be allowed the same considerations as other non-hosts.

The closest IWT to R014 will now be #9 at 1.3 kms.

The closest IWT to R024 will now be #3 at 1.8 kms.

The closest IWT to R056 will now be #15 at 0.9 kms.

The 2012 Draft Guidelines considered 2 kms to be an appropriate set-back distance for non-hosts. The 2016 Wind Energy Guidelines has managed to delete any mention of distance but this does not remove the grave concern that community members living too close to IWTs will be adversely effected.

Despite numerous requests for the States, the Federal Government and the NHMRC to investigate appropriate set back distances, and the impacts of living too close to IWTS, to date none have been undertaken.

We must therefore rely on studies undertaken internationally and the evidence is mounting that setback distances of much greater than 2 kms are needed to ameliorate or eliminate sound impacts.

A recent research paper from Germany is a case in point:

- *Weichenberger, M et al (2017). Altered cortical and subcortical connectivity due to infrasound administered near the hearing threshold – Evidence from fMRI*
<https://doi.org/10.1371/journal.pone.0174420>

The results and conclusion from this study are very important and are tabulated in the Appendix. A careful read of the disturbing findings is recommended.

They strongly suggest that there are adverse health impacts caused by low frequency sound and infrasound generated by industrial wind turbines. These are not negligible health impacts but are potentially serious with ultimately life-threatening implications.

The wind industry has always denied any health effects of wind turbines. In fact the production of infrasound is always denied. Most sound measurements are reported and discussed using dB(A) – A weighted – readings which effectively filter out any infrasound. More realistic measurements could be made using dB(C), dB(G) or indeed unweighted readings which would give a better indication of the presence of low level frequency sound and infrasound. DoPE seems incapable of insisting on these more meaningful measurements.

However, despite the wind industry's assertions to the contrary, there are an increasing number of reports and studies that show that IWTs do produce LFS and infrasound, and that this increases with the size of the IWTs.

All of the Virpac modelling and extrapolation infers the construction of 2.5 MW wind turbines yet no decision has been ever been made public as to what the brand and eventual size of the wind turbines will be at Flyers Creek. In a likely scenario they will be larger with a resulting greater production of LFS and infrasound. **There also appears to be NO planned consequences for Infigen should it exceed its allowable upper noise production.**

Moreover, as pointed out in the FCWTAG's submission, accelerating mining activities and other industrial activities already produce a level of infrasound which is concerning. There has been no effort by Infigen or Virpac to address the problems of cumulative effects. These could be very considerable. It may also lead to a situation where no industrial operation around the Flyers Creek area will take responsibility for the infrasound and LFS in the environment. This however will be of small comfort to those who suffer the ill-effects of infrasound. **It is therefore incumbent on the government (i.e. the DoPE) to protect the community from health impacts that are inevitably going to occur.**

In this very particular instance the residents of R014, R024 and R056 should have those IWTs that are less than 2 km from their property removed, i.e. IWTs 3, 9 and 15.

3. CONCLUSION

The assertions by Infigen that Modification 3 will have a reduced impact on surrounding residents provides no reassurance. Any wind farm of any size will have impacts. To place industrial edifices of the anticipated size of IWTs into a rural (relatively densely populated) environment is a complete travesty.

While we argue the specific impact that will remain for the now non-hosts at R014, R024 and R056 with the retention of IWTs 3,9 and 15, in fact there will be unacceptable impacts for the whole Flyers Creek Wind Farm area.

This wind farm should never have gained DoPE approval in the first place. The area has always been an inappropriate location for a wind farm with its already industrialised activity (mining) and its considerable number of small property holders (particularly at the northern end).

With serial problems now arising in the renewable energy industry itself and with the increasing wind energy being delivered to the grid (intermittency, unreliability, instability of the grid, expensive tax-payer funded subsidisation, the requirement for parallel back-up, rising electricity prices and a host of other environmental, agricultural, health and community problems) it is surely past time for the government to critically assess the complete worthlessness of IWTs.

Approval for the Flyers Creek Wind Farm should be rescinded. History will judge this government poorly as the stupidity and inevitable appalling consequences of the proliferation of IWTs becomes apparent. This fact is already becoming accepted internationally and it is time for Australia to take off its blinkers and make care of its community its top priority.

Alan C Watts OAM

Colleen J Watts OAM

June, 2017

4. APPENDIX

- Weichenberger, M et al (2017). Altered cortical and subcortical connectivity due to infrasound administered near the hearing threshold – Evidence from fMRI
<https://doi.org/10.1371/journal.pone.0174420>

Discussion

The results of the present study can be summed up in the following way: Prolonged IS exposure near the participants' individual hearing threshold led to higher local connectivity in three distinct brain areas—rSTG, ACC and rAmyg—, while no such effect was observed for stimulation above the hearing threshold. Our data also shows that near-threshold IS was associated with connectivity changes on the network level, emphasizing the role of the rAmyg in IS processing. To our knowledge, this study is the first to demonstrate that near-threshold IS does not only produces physiological effects, but that the neural response involves the activation of brain areas, which are important for auditory processing but also for emotional and autonomic control. These findings thus allow us to reflect on how (sub)-liminal IS could give rise to a number of physiological as well as psychological health issues, which until now have only been loosely attributed to noise exposure in the low- and very low-frequency spectrum.

Thus far, evidence regarding the influence of IS on brain activity is limited to two fMRI-studies. Dommes et al. [18] were the first to show that monaural stimulation with a 12-Hz IS tone led to an activation of the bilateral STG, when stimuli were applied at SPLs of 110 as well as 120, but not at 90 dB. However, this pioneering study suffered from the methodological drawback that during 12-Hz stimulation 36-Hz harmonics had been present, which left some room for doubt whether it had really been the IS component that triggered the neural response. In addition, Dommes et al. (2009) were not able to draw reference to psychophysical data about the participants' hearing thresholds or verbal reports and could therefore only speculate that IS exposure at 110 and 120 dB must have led to a hearing sensation, whereas stimulation with 90 dB should not have exceeded the hearing threshold. Recently, Weichenberger et al. [19]

also reported bilateral STG activation in response to supra-threshold IS stimulation, however, in this study an improved setup that prevented higher harmonics from reaching the participants' ear in combination with acoustically well-characterized participants giving verbal reports after the scan session were employed. Surprisingly, we are facing an entirely different situation in the present study, as STG activation was absent during supra-threshold stimulation, but clearly present when IS was administered near the hearing threshold. These results are particularly noteworthy, since not only the experimental setup but also 11 out of the 14 participants were identical across Weichenberger et al.'s [19] and the present investigation. It thus appears that the seemingly contradictory results cannot be attributed to different instrumentation or participants, but rather point towards truly different neural responses which have been uncovered due to the nature of data acquisition as well as the time course of stimulus application chosen in this study. Since we were interested in studying the brain's response to IS under conditions, which more closely resemble those found outside of the laboratory, we chose significantly longer stimulus intervals (200 s) and also provided a constant level of stimulation throughout the entire interval. This is in contrast to the aforementioned studies, in which short stimulus intervals consisting of multiple successive tone bursts (1 and 3 s respectively) with interleaved image acquisitions were employed. The absence of STG activation during supra-threshold IS exposure could therefore be the result of stimulus-specific adaptation, according to which the BOLD signal gradually decreases in response to ongoing stimulus administration [68–69]. However, although stimulus-specific adaptation times of up to tens of seconds have been reported in the auditory cortex of animals [70], nothing is known about adaptation over comparable time-scales in humans. In addition, this explanation cannot account for why near-threshold stimulation would be affected to a lesser extent by such mechanisms. In contrast, we hypothesize that our results rather reflect the complex involvement of different physiological processes in response to near-threshold and supra-threshold IS, as well as the interference of attentional effects, which may play an increasingly important role when stimuli are presented over longer durations. Several studies provide evidence for the existence of a 'subconscious hearing route' for IS, according to which IS may exert effects on the organism via outer hair cells, even if presented at SPLs below the hearing threshold [71, 31]. While inner hair cells—the main signal transducers involved in 'conscious hearing'—connect with fusiform cells of the cochlear nucleus from which the signal is then relayed to higher levels of the auditory system, outer hair cells terminate in the granule cell regions of the cochlear nucleus [72] and from there on connect to numerous auditory as well as non-auditory cortical processing sites [73]. Importantly, since some of these centres are involved in attentional control and arousal [74], it has been suggested that activation of this pathway could for example wake people up at night, while leaving them unable to pin down what it actually was that caused them to waken [75]. Similarly, in our experiment,

participants were constantly left guessing, whether stimulation actually occurred or not when near-threshold IS was presented, whereas during supra-threshold stimulation, participants were clearly able to allocate attention towards or away from the percept throughout the entire stimulus interval. We therefore suggest that persistent exposure to supra-threshold IS may have led to a top-down attenuation of the signal via attentional mechanisms, whereas in the absence of a clearly identifiable percept, STG activation remained high. However, it needs to be mentioned that the average (median) SPL of the supra-threshold stimulus (122,3 dB SPL, as determined via individual loudness scaling) was very close to the safety limit of 124 dB SPL, which probably points towards the presence of a ceiling effect. We therefore cannot rule out that participants may have reported a medium-loud hearing sensation at even higher SPLs, if our ethical guidelines would have allowed us to apply stimuli at such intensities. The ceiling effect may have led to slight discrepancies with respect to inter-individual loudness perception during the supra-threshold runs and thus have produced additional variability in our imaging data. Nevertheless, we conclude that the effect was probably not pronounced enough to suppress an otherwise significant effect. It also needs to be noted that in contrast to the aforementioned studies on IS processing, near-threshold stimulation led to a cortical response of the ipsilateral side, as compared to a bi-hemispheric, yet also stronger response of the contralateral side (i.e. the left auditory cortex) when supra-threshold stimulation was employed [18–19]. This touches on the aspect of a presumed lateralization of the auditory system, the true nature of which is still part of an ongoing debate, as evidence both in favor of a contralateral dominance for monaurally presented sounds [76–77], as well as a left hemispherical preference irrespective of which ear is stimulated (Devlin et al., 2003) [78] has been put forward. It thus appears that while the preceding accounts seem to support the notion of “contralateral dominance” extending to sounds in the infrasound spectrum, the results of the present studies could rather be explained by the fact that evoked otoacoustic emissions (which are generated via outer hair cells) also tend to be more pronounced on the right ear [79–80]. However, more information needs to be gathered on how OHC signals are processed up-stream on the level of the brainstem, and in what way OHC activation influences the activity of auditory (and possibly non-auditory) centres.

The ACC is generally regarded as a key player in the monitoring and resolution of cognitive [81–83], as well as emotional conflicts [84–87]. Interestingly, a recent meta-analysis by Meneguzzo et al. [88] also revealed that the ACC reliably exhibits activation in response to both sub- as well as supraliminally presented arousing stimuli, which led the authors to suggest that this brain area may function as a gateway between automatic (‘pre-attentive’) affective states and higher order cognitive processes, particularly when affect and cognition are in conflict. In addition, the authors explicitly gave credit to the

fact that the term ‘conflict’ may also include unexpected perturbations of the body’s physiology in the absence of conscious awareness. Moreover, another line of research also highlights the ACC’s involvement in autonomic control via its extensive connections with the insula, prefrontal cortex, amygdala, hypothalamus and the brainstem [89–90]. ACC activation in response to near-threshold IS stimulation could therefore be interpreted as a conflict signalling registration of the stimulus which, if not resolved, may lead to changes of autonomic function.

Similarly, the amygdala is well known for its involvement in emotional processing, especially with respect to fear conditioning, but also in the broader context of stress- and anxiety-related psychiatric disorders [91]. Several studies have documented activation of the amygdala in response to aversive sensory stimuli across different modalities, such as odorants [92], tastes [93], visual stimuli [94–96], as well as in response to emotional vocalization [97–99] and unconditioned sounds that are experienced as aversive [100–102]. Activation of the rAmyg during near-threshold IS exposure may be of particular interest for a risk assessment regarding IS, because the amygdala is known to be involved in auditory processing and may also play a major role in debilitating tinnitus and hyperacusis [103]. It is a fairly established finding that auditory input can be processed along two separate neural pathways, the classical (lemniscal) and the non-classical (extralemniscal) pathway [104–105]. While signals travelling along the classical pathway are relayed via ventral thalamic nuclei mostly to the primary auditory cortex, signals traveling along the non-classical pathway are bypassing the primary auditory cortex as dorsal thalamic nuclei project to secondary- and association cortices and also to parts of the limbic structure such as the amygdala. Importantly, the non-classical pathway (frequently called the ‘low route’) allows for direct subcortical processing of the stimulus in the amygdala, without the involvement of cortical areas [106–107] and may therefore play a crucial role in the subliminal registration of ‘biologically meaningful’ stimuli, such as near-threshold IS. In fact, it has been suggested that in certain forms of tinnitus, activation of the non-classical pathway can mediate fear without conscious control [108] and, via its connections to the reticular formation [109], also exert influences on wakefulness and arousal. Additional evidence for the amygdala’s involvement in subliminal processing and autonomic control comes from a study conducted by Gläscher and Adolphs [110], in which patients with unilateral as well as bilateral lesions of the amygdala were presented emotional visual stimuli of varying arousal sub- as well as supraliminally, while skin conductance responses (SCRs) were recorded as a measure of autonomic activation. Interestingly, it could be shown that the left amygdala decodes the arousal signalled by the specific stimulus (linked to a conscious fear response), whereas the rAmyg provides a global level of autonomic activation triggered automatically by any arousing stimulus (linked

to a subconscious fear response). It is particularly noteworthy that while the rAmyg exhibited increased local connectivity in response to near-threshold IS, ICA revealed a decoupling of the rAmyg from the sensorimotor network in comparison to the no-tone condition. It has been repeatedly argued that decoupling of the amygdala from areas involved in executive control may enable an organism to sustain attention and supports working memory [111], thus potentially aiding cognitive control processes in the aftermath of stress [112]. Interestingly, the fact that functional connectivity of the rSFG was higher during near-threshold stimulation further substantiates this claim. Again, several studies demonstrate that rSFG and rAmyg share functional connections and that activity between the two regions tends to be negatively correlated [113, 112]. Thus, participants who were left guessing whether stimulation occurred, may have engaged in effortful regulation of affect, trying to minimize the consequences of stress on cognitive control networks.

Finally, our results also allow us to draw some preliminary conclusions on potential long-term health effects associated with (sub-)liminal IS stimulation. It has been reported in several studies that sustained exposure to noise can lead to an increase of catecholamine- and cortisol levels [114–116]. In addition, changes of bodily functions, such as blood pressure, respiration rate, EEG patterns and heart rate have also been documented in the context of exposure to below- and near-threshold IS [117–118]. We therefore suggest that several of the above mentioned autonomic reactions could in fact be mediated by the activation of brain areas such as the ACC and the amygdala. While increased local connectivity in ACC and rAmyg may only reflect an initial bodily stress response towards (sub-)liminal IS, we speculate that stimulation over longer periods of time could exert a profound effect on autonomic functions and may eventually lead to the formation of symptoms such as sleep disturbances, panic attacks or depression, especially when additional risk factors, such as an increased sensibility towards noise, or strong expectations about the harmfulness of IS are present. Also, while in this discussion, we put a strong emphasize on the physiological implications of prolonged IS exposure, it would also be interesting to see, whether our rsfMRI paradigm could be used to relate IS-induced changes of global-brain states and changes in the experiential domain.

Conclusion

To our knowledge, this study is the first to document changes of brain activity across several regions in response to prolonged near-threshold IS using fMRI. ReHo analysis

revealed higher local connectivity of rSTG, ACC and the rAmyg only when IS was administered near the hearing threshold and ICA showed that effects can also be found on the inter-regional level. On the one hand, these results seem to support the hypothesis that (sub-)liminal IS can exert an influence on the organism via a subconscious processing route (which supposedly involves outer hair cell-mediated signal transduction). On the other hand, though clearly audible, prolonged stimulation with IS above the hearing threshold did not lead to changes of brain activity, which could indicate that the signal processed along the conscious hearing route may have been attenuated in a top-down fashion via attentional mechanisms. Also, since the brain's response to prolonged near-threshold IS involves the activation of brain areas, which are known to play a crucial role in emotional and autonomic control, a potential link between IS-induced changes of brain activity and the emergence of various physiological as well as psychological health effects can be established. Transient upregulation of these brain areas in response to below- or near threshold IS may thus reflect an initial stress response of the body, eventually promoting symptom formation as stimulation occurs repeatedly and additional risk factors come into play. Nevertheless, further research, in particular longitudinal exposure research, is needed in order to substantiate these findings and contribute to a better understanding of IS-related health effects.