Quality of Life
Health
Development

NORAH
Knowledge No. 14

NORAH Noise Impact Study

Overview of results

forum flughafen & region
umwelt- und nachbarschaftshaus

NORAH

Knowledge No. 14

NORAH Noise Impact Study

Overview of results

"NORAH Knowledge" provides information on the methods and results of the NORAH noise impact study. The aim of this series is to communicate to as many people as possible what exactly NORAH researched. This is why there is an explanation in the glossary at the end for all terms marked "▯ glossary".

If you would like to receive further issues of "NORAH Knowledge", please use the enclosed order form.

The NORAH Study investigated the effects of aircraft, road and rail traffic noise on humans.

von Aichberger

NORAH ("Noise-Related Annoyance, Cognition, and Health") is the most extensive investigation into the effects of exposure to aircraft, road and rail traffic noise that has ever been carried out in Germany. It was conducted by nine independent scientific institutes from all over Germany. The client was the Umwelt- und Nachbarschaftshaus, a subsidiary of the state of Hessen and part of the "Forum Flughafen und Region". Alongside the state of Hessen, communities, Fraport AG and Lufthansa were also involved in the financing.

The NORAH Study examined the long-term effects of traffic noise on health, quality of life and early childhood development in the Rhine-Main Region. The initiator of the study was the Airport and Region Forum (ARF). The scientists were accompanied from the start by an external Scientific Advisory Board for Quality Assurance (WBQ). This is what distinguishes NORAH from similar predecessor studies. The study addressed some of the most topical important issues currently being dealt with by international noise impact research. It also covered a wider range of investigation aspects than previous studies. In order to find out more about how human beings respond to traffic noise, the NORAH scientists also looked at the medical histories of more than one million people, and reconstructed the noise exposure at around 900,000 addresses in the Rhine-Main Region.

A total of five sub-studies form the core of the NORAH Study. Each one built on the current international state of research. In addition to this, extremely complex and innovative techniques were used to calculate the acoustic exposure. In this edition of "NORAH Knowledge" we present the most important results of the entire NORAH Study. You can read a more detailed presentation of the results of the individual sub-studies in "NORAH Knowledge" no. 4 as well as no. 10 to 13.

Contents

Further information on the NORAH Study is available on the Internet at **www.laermstudie.de**. There you can also subscribe to the newsletter "NORAH Brief".

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NORAH OVERVIEW

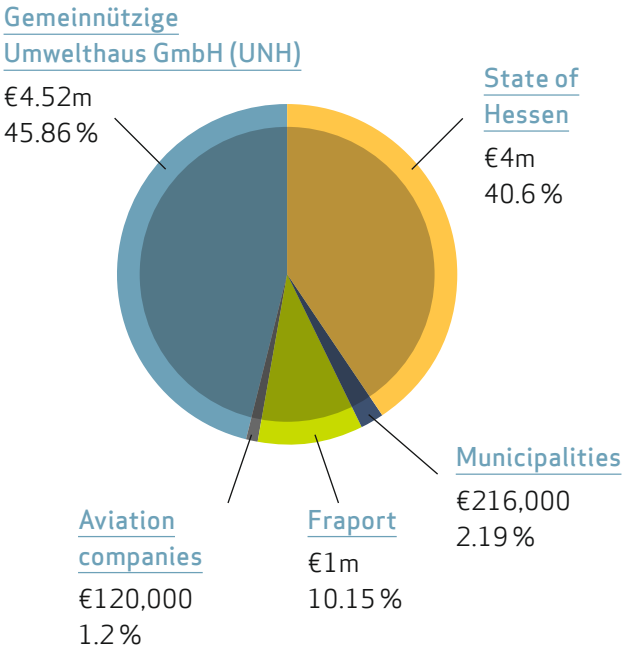
In October 2015, the results of the NORAH Study were presented to the public. They are the result of nearly five years of research. In September 2010, the state of Hessen decided to provide the Forum Flughafen und Region (FFR) with funds for a comprehensive examination of the health effects of traffic noise. After a public tender, a group of nine scientific facilities under the management of the Ruhr University Bochum was charged with executing these examinations in April 2011. At the same time, a scientific advisory council was installed. It consisted of experienced and independent experts of all specialisations involved. They observed that the study parts were performed with care and ensured that all required quality standards were complied with.

Apart from tinnitus (ringing in the ears), the five sub-studies of NORAH examined all effects of noise named by the World Health Organization (WHO):

- Annoyance and impairment of the quality of life
- Health risks
- Effects on sleep
- Effects on blood pressure
- Effects on cognitive performance and quality of life of children

The targets of NORAH

The target of the NORAH Study was to record the effects of traffic noise on residents in the Rhine-Main Region. Especially, it was to put the discussion on flight noise effects that has long been conducted in the Frankfurt area on an objective and scientific basis. Therefore, apart from the principal, citizens' initiatives, municipalities and aviation representatives were also involved in the development of the questions. The costs were mostly assumed by the state of Hessen, while aviation companies Fraport and Lufthansa bore about eleven percent. Apart from this, eight municipalities from the area participated, as well as the Initiative Zukunft Rhein-Main (with municipalities, associations and citizens' initiatives as members). The principal was the Gemeinnützige Umwelthaus GmbH, as subsidiary of the state of Hessen and part of the Forum Flughafen und Region.



Questions of the NORAH Study

Study on Quality of Life

How much do residents feel disturbed by traffic noise? How does it affect their quality of life? What kind of noise is most disturbing: road, rail or air traffic noise? How does the annoyance change when flight noise increases or reduces due to changes of flight operation? Do people in the Frankfurt area react to noise the same way or differently from, e.g. those near the airports of Cologne/Bonn or Stuttgart? In addition to answering these and some other questions, the annoyance study aimed to update so-called exposure-effect (annoyance) curves. They can be used to read the degree of annoyance and disturbance depending on the noise load. They play an important role in making decisions on noise protection measures.

Study on Health Risks

How much does chronic traffic noise affect the health of the adult residents of the Rhine-Main area? The focus was on various cardiovascular diseases, depression (glossary) and breast cancer. For these, NORAH aimed to determine the connection between noise and health risk as precisely as possible, in the form of so-called exposure–risk relationships (glossary).

Sleep Study

The Sleep Study aimed to find out how introduction of the core resting time between 11 p.m. and 5 a.m. in 2011 affected the sleep of the residents near the Frankfurt airport. Another aim was to examine whether the results of sleep studies at the airport Cologne/Bonn from 2001/2002, which are currently used for the Frankfurt night index, differ from the current results in the Frankfurt area.

Blood Pressure Study

Noise can cause stress. Stress will increase blood pressure in the short term – this is the starting thesis of the study. How does blood pressure react to chronic traffic noise, however? Do the residents of the Frankfurt airport area show effects that cannot be explained by typical risk factors such as age, smoking or overweight, but that are connected to noise level?

Children's Study

Do primary school children learn to read more slowly when they are going to school or living in areas strongly exposed to aircraft noise? How does noise affect their quality of life? Again, the aim was to determine the exposure–effect curves (glossary) – in this case for children.

foto-rolf/istockphoto

Deutscher Verkehrssicherheitsrat (DVR)

Deutsche Bahn

THE MOST IMPORTANT RESULTS

The following pages summarise the five sub-studies on one double page each. We can only briefly sketch the results – all in all, the scientific reports of NORAH comprise approx. 2,500 pages. For more information, see the "NORAH Knowledge" booklets no. 4 and no. 10 to 13, which you can order via the order form in the booklet or download from the website **www.laermstudie.de** in the area "Wissen/Knowledge". Of course, our website will also give you access to the scientific result reports, including the associated statements of the Scientific Advisory Board for Quality Assurance.

Quality of Life and Annoyance

The residents of the Frankfurt airport area felt more annoyed by the aircraft noise with the same long-term energy equivalent noise level (glossary) than in earlier studies. The annoyance at the examined comparison airports was also clearly above the EU-standard curves used in several national and European noise directives. As compared to the airports Cologne/Bonn and Stuttgart, people in Frankfurt felt more strongly annoyed at the same noise level. The annoyance increased at first after opening of the north-west runway in 2011 and dropped again in 2013, but remained above the level of 2011. Scientists call this a "change effect" (glossary) in connection with development of the airport. They were also able to prove that aircraft noise annoys people more than road or rail noise. *(For more, see page 6.)*

Study on Health Risks

The study was able to show a connection between all three examined traffic types and the occurrence of heart attack, stroke, heart insufficiency (weak heart) and depression (glossary). However, it was not consistent across noise types and pathologies. *(For more, see page 8.)*

Sleep Study

Since introduction of the night core resting time in 2011, the residents near the airport wake up less frequently at night. Nevertheless, they often feel tired in the morning. Persons who have a rather critical attitude towards aircraft traffic generally sleep less well than those supporting it. The results from earlier sleep studies at the airport Cologne/Bonn can only be partially transferred to Frankfurt. *(For more, see page 10/11.)*

Blood Pressure Study

The study could not confirm with statistical certainty that chronic aircraft noise increases blood pressure. This result partially contradicts results of earlier studies, but all in all is comparable to the most of the previous research. However, it is also based on far more and more accurate blood pressure measurements and more precise acoustic and survey data than were available in earlier studies. For road and rail traffic noise, the overall group also showed no statistically significant (glossary) effects on blood pressure. The blood pressure increases found are in the range of a few millimetres on the mercury column – this is less than the measuring inaccuracy of a normal blood pressure meter. Increases at this scope are irrelevant for the development of cardiovascular diseases. However, there were indications of particularly sensitive groups. *(For more, see page 12.)*

Children's Study

Primary school children learn to read more slowly in areas subject to strong aircraft noise than in more quiet areas. A noise increase of 10 dB (glossary) delays learning to read by one month. Effects of aircraft noise on foundational skills of reading, such as sound processing or auditory understanding could not be documented by NORAH. Children in very noisy areas are less well in terms of health than children in more quiet locations. Their parents also stated more frequently that their child had already been diagnosed with a speech or language impairment. Teachers from areas comparatively strongly subject to aircraft noise report correspondingly that the noise disturbed lessons considerably.

QUALITY OF LIFE AND ANNOYANCE

The Quality of Life Study examined the connection between the objectively measurable noise level and the statements of people who hear the noise about their subjective experience. It deals with this context from three angles:

- Over time: How does the annoyance develop when the noise changes, e.g. after development of an airport?
- By comparison between noise sources: How does aircraft noise act as compared to road or rail noise?
- By site comparison: Do people in the Rhine-Main area evaluate traffic noise differently from people in Cologne, Stuttgart or Berlin?

To answer these questions, the scientists questioned people in the area of the airports and then put their answers in relationships with the noise level in the respective place of residence. They used this to develop annoyance curves, and then used the position and pitch of these curves to derive statements on how people react to noise. For authorities, annoyance curves are an important basis to evaluate noise protection measures.

The surveys covered:

- about 19,000 people in the Rhine-Main area
- about 10,000 people in the area of the airports Cologne/Bonn, Stuttgart and Berlin-Brandenburg

Time comparison: annoyance increased

The NORAH team surveyed the people in the Rhine-Main area in 2011, 2012 and 2013 and then compared the annoyance curves. The respondents felt annoyed the strongest – at the same noise level – in 2012, i.e. the year after the new runway was opened. The scientists were able to document a change effect (glossary): respondents at whose place of residence the noise increased in 2012 felt more annoyed after the change than people where the comparable noise level had been present for years. Respondents where the noise level had not changed at all also felt more strongly annoyed in 2012 than before. The annoyance reduced slightly in 2013, but did not return to the level of 2011.

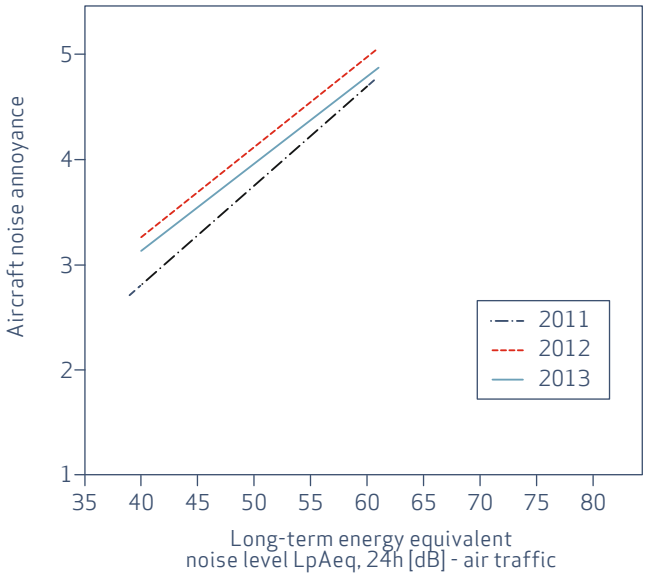
The degree of this change effect depended on three factors:

- the self-assessment of the participants of how well they could handle noise
- their attitude towards air traffic
- their expectation of how future flight operations would affect their residential situation

For example, those who expected that the noise at their places of residence would reduce felt less annoyed at the same level than those who expected the noise to increase.

The comparison with an older study from the Frankfurt area ("RDF Study") also showed that the annoyance has increased in general since 2005. Accordingly, the residents are feeling much more annoyed at the same noise level today than in 2011. The comparison airports Cologne/Bonn and Stuttgart also have much higher annoyance values than would be expected according to the EU standard curves.

Comparison over time



The figure shows the interrelation between aircraft noise and annoyance in the three examination years. In 2012 – the year after opening of the new runway – the people in the Rhine-Main area felt the most strongly annoyed. Annoyance reduced again in 2013.

Schreckenberg/ZEUS

Site comparison

The four airports in the area of which the NORAH team questioned residents differ considerably from each other – in their sizes, regarding the planned construction projects and also in terms of night aircraft traffic. It became clear that people in the Frankfurt area feel more strongly disturbed at the same long-term energy equivalent noise level (glossary) than people near the other airports. The second place is held by the airport Cologne/Bonn. People in the Stuttgart area feel least disturbed by aircraft noise.

Comparison of the noise sources

In addition to aircraft noise, the NORAH Study also calculated the road and rail noise in the Rhine-Main area and asked the residents how badly they felt annoyed by which noise type. It became evident that aircraft noise annoyed people more strongly even at relatively low noise levels than much louder rail and road traffic noise.

For more information on the Quality of Life Study, see the "NORAH Knowledge" booklets no. 7 (Methods) and no. 13 (Results).

HEALTH RISKS

The Study on Health Risks focuses on five diseases: heart attack, stroke, weak heart (or heart insufficiency), depression (glossary) and breast cancer. All five diseases are widespread in Germany. They also have another thing in common: studies have suggested in the past that all of these diseases occur with above-average frequency in persons who are exposed to a lot of traffic noise every day.

The Study on Health Risks followed this suspicion. The scientists evaluated health insurance data of about one million persons in the Rhine-Main area. For this, the NORAH team cooperated with three large health insurers in the Rhine-Main area. In parallel, the NORAH acousticians calculated the stress from aircraft, road and rail noise at all addresses in the Rhine-Main area, in some cases retroactively back to 1996. A special data privacy procedure secured anonymity of the study participants. In the end, the NORAH team knew how many insured persons had one of the five diseases and how much noise there was at the place of residence of the affected person, but not where these persons lived or what their names were. Several thousand persons additionally participated in a deeper survey to help the scientists gain further insights into heart insufficiency.

Cardiovascular risk in traffic noise increased

The NORAH Study proves that traffic noise can increase the risk of developing heart attack, stroke or heart insufficiency. When only considering the long-term energy equivalent noise level (glossary), the highest risk for a weak heart came with rail noise, followed by road and aircraft noise.

There were indications that the duration of stress from noise was relevant for the cardiovascular risk. Regarding stroke, the scientists were also able to find a statistically significant (glossary) connection with all three examined traffic noise types – i.e. aircraft, road and rail noise. However, aircraft noise did not lead to any increase, but rather a reduction of the stroke risk at rising long-term energy equivalent noise level. A statistically significant increase of the stroke risk from aircraft noise was only shown when considering the maximum aircraft noise level at night. For heart attack, a connection between road and rail noise can be documented, and for the insured persons who died during the examination period also with aircraft noise. Depending on disease, noise type and examined group of persons, the risk therefore increases by up to 3.9 percent per 10 dB (glossary) traffic noise increase.

When only considering long-term energy equivalent noise level, the highest risk for a weak heart was found in rail noise, followed by road and aircraft noise.

Monkey Business Images / Shutterstock

Depression: Traffic noise increases the risk of disease

All three traffic noise types can contribute to developing depression. The scientists were able to calculate that the risk of a depressive episode increases by 8.9 percent on average when the aircraft noise stress increases by 10 dB. For road noise, the risk increases by 4.1 percent per 10 dB, and for rail noise by 3.9 percent. However, these averages only partially reflect the study results. For aircraft and rail noise, the NORAH team determined that the risk seems to drop again at very high noise levels. One possible explanation of this observation would be that people who tend to develop depression more frequently move to more quiet locations.

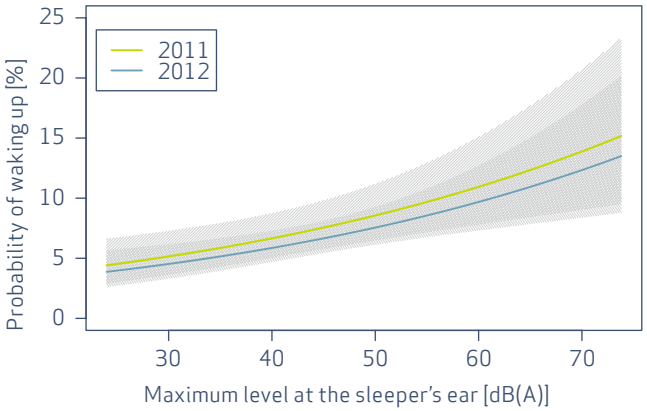
Breast cancer: Further research required

A possible influence of traffic noise on the development of breast cancer was only suggested by three studies before NORAH. Therefore, there was less proof for this connection from the beginning than for cardiovascular diseases, for example. The NORAH Study was unable to confirm that road or rail noise can contribute to the development of breast cancer. For aircraft noise, however, the scientists found a small connection: in the group of persons exposed to a long-term energy equivalent noise level above 55 dB between 11 p.m. and 5 a.m., there were more cases of breast cancer than expected. More research on this subject will be necessary: safe conclusions are not possible yet.

SLEEP

For the Sleep Study, the scientists measured the sleep quality of persons affected by aircraft noise in the Rhine-Main area for three to four nights at a time. All in all, more than 200 persons were examined. The study participants slept in their usual home, but with several electrodes (glossary) on their bodies. At the same time, a noise level meter recorded all sounds that reached the sleepers' ears at night. The first measurements took place in summer 2011, i.e. before introduction of the core resting time and opening of the north-west runway. In the summers of 2012 and 2013, further measuring phases followed, some performed on the same persons.

Aircraft noise-associated wake-up probability



The figure shows the probability of waking up during a flight at a certain maximum level. This did not differ significantly (glossary) between 2011 and 2012. This is evident by the strong overlap of the hatched "trust areas" (confidence intervals).

Müller/DLR

Residents wake up less often since the night aircraft restrictions

The prohibition of planned starts and landings between 11 p.m. and 5 a.m. achieved an important goal: the residents at the Frankfurt airport woke up less often in 2012 than in the prior year, due to the smaller number of night flights. The probability of waking up at a night flight did not differ in the years of 2011 and 2012, however. In 2012, such participants who went to bed later and thus noticed more of the flights after 5 a.m. during their sleeping time woke up more often, though. This group of "late sleepers" did not differ from the "early sleepers" in typical indices of sleep research, however: they spent the same share of their bed time sleeping ("sleep efficiency") and were not awake between 4:30 a.m. and the end of their "bedtime" any longer than neighbours who went to bed an hour earlier.

This objectively measured reduction of the wake-up reactions is, however, not reflected in the personal evaluations of the participants. They stated that they were tired and sleepy during the day – no matter the aircraft noise burden – with a slightly increasing tendency from 2011 to 2013. The scientists cannot derive any explanation for this effect from the data. Therefore, it must be due to factors that the study did not examine.

Do airport critics sleep less well?

Participants of the study were asked, among other things, how they assessed aircraft traffic in general. A comparison with the sleep measurements showed that people with a negative attitude towards aircraft traffic slept less well than those participants who saw aircraft traffic positively. Among other things, they needed more time to fall asleep, spent less time in deep sleep and were lying awake for longer. This is a purely statistical interrelation. NORAH could not determine whether the negative attitude was the cause or consequence of the bad sleep. Both would be possible.

Cologne/Bonn data not easily transferrable

Insights of sleep studies in the area of the Cologne/Bonn airport from 2001/2002 cannot just be transferred to the Rhine-Main area, because aircraft noise and its effects are too different in the two locations. Cologne/Bonn continually has flights at night. Therefore test persons in the Rhineland woke up at night more often and spent less time in deep sleep than in the Frankfurt area after the core resting time was introduced. The probability of waking up from aircraft noise at a certain maximum level only moderately differed between the two studies. Generally, however, the NORAH participants felt clearly more disturbed by aircraft noise of the previous night in 2013 than the test persons from the Cologne/Bonn study in 2001/2002.

New method

Usually, sleep examinations monitor many body functions, including brain currents. NORAH was able to show that a relatively simple measurement of pulse and body movement may be enough to reliably describe important reactions of sleepers to noise. This way, scientists spare their test subjects the application of many electrodes. The new method, called the "vegetative-motoric" method (VMM), can be applied independently by the test persons and automatically evaluated, thus permitting sleep studies with a lot more participants than before. However, the scientific inductiveness of this new method should be confirmed in further studies.

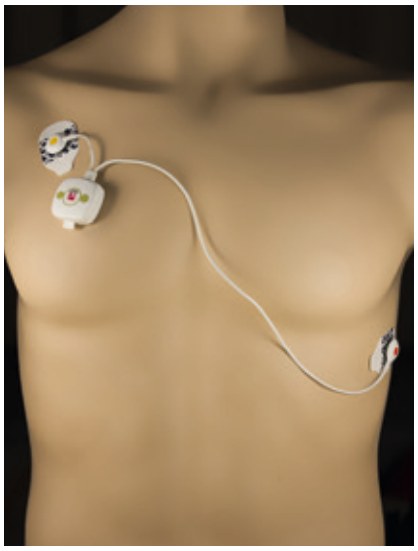
For more information on the Sleep Study, see the "NORAH Knowledge" booklets no. 5 (Methods) and no. 10 (Results).

Comparison between early and late sleepers

	2001: Sleep time: 10/10.30 p.m. to 6/6.30 a.m.	2012: Sleep time: 10/10.30 p.m. to 6/6.30 a.m.	2012: Sleep time: 11/11.30 p.m. to 7/7.30 a.m.
Total duration of sleep	7:06 hrs	7:08 hrs	7:07 hrs
Duration between going to bed and falling asleep	13.9 min	14.5 min	13.1 min
Sleep efficiency *(share of sleep in time in bed)*	90%	90%	91%
Duration of being awake after falling asleep in min	36.7 min	34.4 min	33.8 min
Difference bet. planned and actual sleep end in min	3.3 min	5.4 min	5.7 min
Share of being awake in percent between 4:30 a.m. and planned end of sleep	14%	14%	12%

The group of the "early sleepers" did not differ from the "late sleepers" who go to bed between 11 and 11:30 p.m. in typical indices of sleep research.

For the "vegetative-motoric" method, only two electrodes need to be attached to the body. They measure movement and heartbeat of the examined person.



Knost/DLR

BLOOD PRESSURE

The Blood Pressure Study had more than 1,000 participants from the environment of the Frankfurt airport, including 844 who could be included in the evaluation. For three weeks, the participants measured their own blood pressure in the mornings and evenings. These measurements were repeated one year later. The values were automatically submitted to the NORAH team by mobile phone via a safe line and saved on a data server.

Low effects of aircraft, road and rail traffic noise

No statistically significant (glossary) interrelation could be found between the long-term energy equivalent aircraft noise level (glossary) from 6 p.m. to 6 a.m. and the following parameters relevant for the cardiovascular system: blood pressure, heart frequency and blood pressure amplitude (the difference between the upper and lower value of a blood pressure measurement). The same is true for road and rail traffic noise: again, the NORAH team could not document any statistically clear relationship for any measured value. The study included many other factors, such as age, gender, social status, medication, being overweight or smoking. Even though many of these factors have been controlled by statistical procedures, no significant connection could be documented between aircraft noise and blood pressure. The NORAH team also examined other day and night periods than from 6 p.m. to 6 a.m. and always came to similar results.

Significant connection between aircraft noise and blood pressure not evident.

Some people react more strongly

There are indications that the increase of blood pressure in connection with traffic noise is stronger in some groups. Differences in noise sensitivity, age, gender, time of residence and hypertension play a role here. However, this was not the same for the three noise types. A significant (glossary) connection between chronic noise exposure and blood pressure could not be documented in the respective partial groups either.

Method strengths

All in all, the results of the NORAH Blood Pressure Study are comparable to most prior research. Only few prior studies had shown indications of a connection between aircraft noise and blood pressure. These took place using a much smaller data basis. The method of the NORAH Study has several strengths by comparison with these examinations:

- Self-measurement of the blood pressure according to a consistent, specified procedure instead of self-reported diagnoses or health insurance data; this leads to reliable measured values without influences from the examined persons.
- Daily measurements for three weeks and repetition after twelve months instead of individual values or pointed measurements as in other studies.
- Consideration of three traffic noise types.
- Address-specific assignment of the calculated noise exposure, sorted by noise type and time of the day.
- Very precise level data going back one year.
- Consideration of many health-related and social parameters.
- Recording the applied prescription and non-prescription medicines of the last seven days.

For more information on the Blood Pressure Study, see the "NORAH Knowledge" booklets no. 8 (Methods) and no. 11 (Results).

The participants measured their blood pressure every morning and evening. The data were submitted directly to the NORAH team's server via Bluetooth® and a mobile phone.

zur Nieden

CHILDREN

How does aircraft noise affect children's development and quality of life? The Children's Study dealt with these questions in the scope of NORAH. For this, the scientists of the NORAH team performed tests, surveys and measurements in 29 schools and 85 classes, with the participation of 1,243 children, 1,185 parents and 85 teachers in the Rhine-Main area.

The study focused on learning to read, health and well-being of the children at school, as well as noise exposure when studying at home and at school. It thus directly connects to earlier studies in other locations and tries to answer questions that are still open.

Aircraft noise reduces learning performance

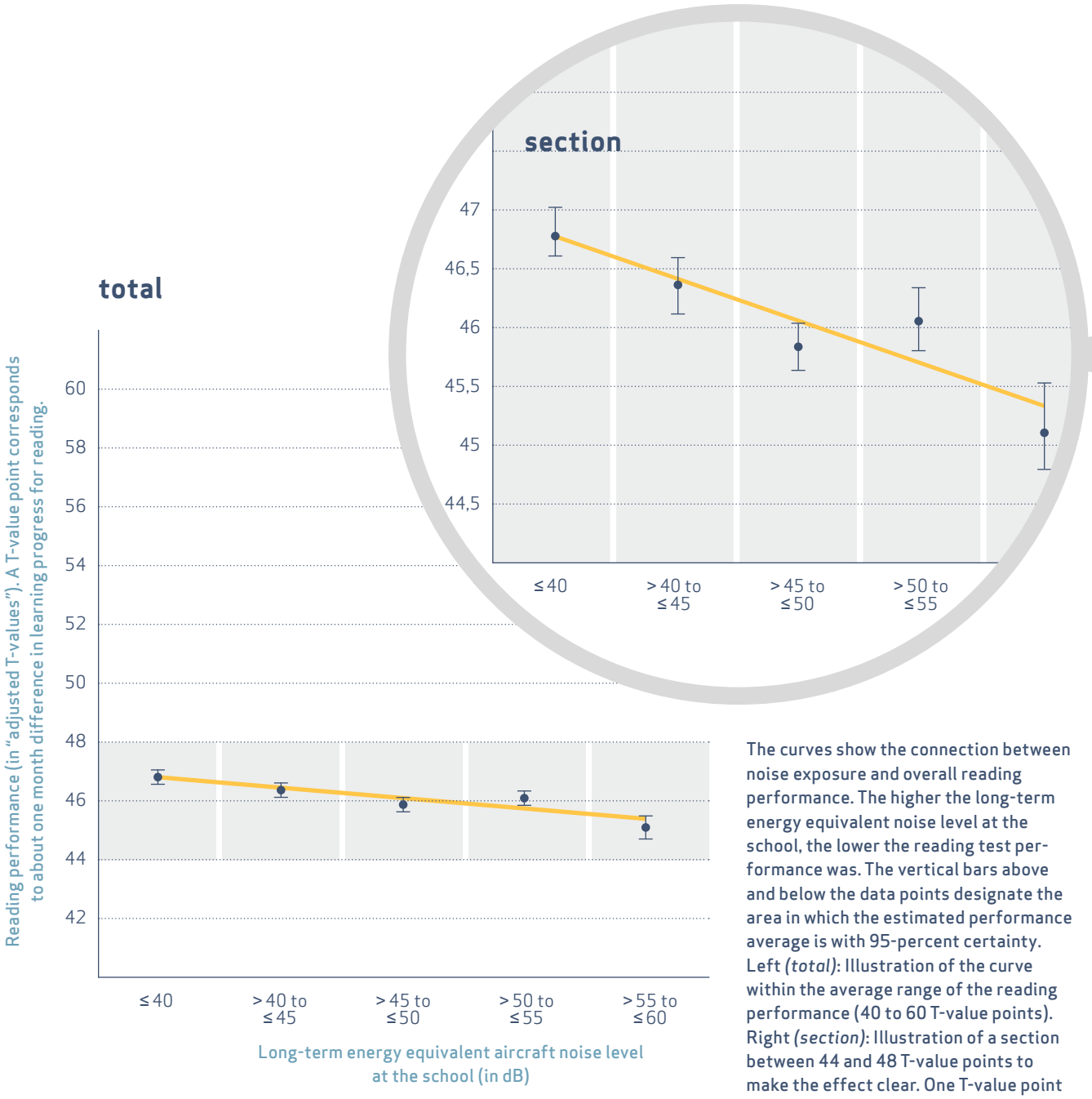
In areas strongly exposed to aircraft noise, primary school children learn to read more slowly than children in quieter areas. Among the examined second-grade children, an increase of the long-term energy equivalent noise level (glossary) by 10 dB (glossary) delayed learning to read by one month. The connection is linear: the stronger the exposure, the stronger the impairment of development. Direct effects of aircraft noise on foundational skills of reading such as acoustic processing or auditory understanding could not be proven by NORAH in contrast to this.

School and health quality of life slightly impaired

All in all, the quality of life of the examined children in the Rhine-Main area is high – most second-graders feel very well, are healthy and like going to school. Children in areas strongly exposed to noise feel a little less well in terms of health than children in more quiet areas, however. Additionally, the respondent parents in areas comparably strongly exposed to noise stated more often that their children took prescription medicines or had been diagnosed with a speech or language impairment. The affected children did not differ in their reading performance from the other children, however.

With standardised tests, the NORAH team examined the reading skills and foundational skills of the children.

Bergström



Klatte / TU Kaiserslautern

The curves show the connection between noise exposure and overall reading performance. The higher the long-term energy equivalent noise level at the school, the lower the reading test performance was. The vertical bars above and below the data points designate the area in which the estimated performance average is with 95-percent certainty. Left *(total)*: Illustration of the curve within the average range of the reading performance (40 to 60 T-value points). Right *(section)*: Illustration of a section between 44 and 48 T-value points to make the effect clear. One T-value point corresponds to about one month difference in learning progress.

Aircraft noise disturbs lessons

Teachers from areas comparably strongly exposed to aircraft noise report correspondingly that the noise considerably disturbs lessons. Lessons are interrupted in diverse manners by aircraft noise, and the children's attention is often distracted. More than one-third of the children from these schools sometimes have trouble understanding the teacher due to aircraft noise.

The NORAH Children's Study was presented to the public in autumn 2014. It has already led to a resolution of the state government of Hessen to improve sound insulation of schools that are subject to high exposure to aircraft noise.

For more information on the Children's Study, see "NORAH Knowledge" no. 1 (Method) and no. 4 (Results).

ACOUSTIC BASIS

Determination of the noise exposure is the foundation of a noise effect study. The acousticians of the NORAH Study put a lot of energy into this area. They calculated the exposure to aircraft, road and rail traffic noise in the Frankfurt area for the addresses of about 900,000 buildings, at different day and night times and for up to 18 years into the past. Additionally, they collected noise data of 2,500 residents in the area of each of the airports Cologne/Bonn and Stuttgart and about 5,000 residents at the airport Berlin-Brandenburg, which is under construction.

Aircraft noise calculation

The aircraft noise data of the NORAH Study have been calculated based on radar recordings of the German flight safety authority. By comparison to noise levels measured on site, the acousticians were able to document that the calculated levels map the actual exposure very well.

The NORAH acoustic database

The NORAH acoustic database contains about 30 "acoustic characteristics" for every study participant, among others long-term energy equivalent noise level (glossary) for day (6 a.m.– 10 p.m.) and night (10 p.m. – 6 a.m.), average maximum levels (glossary) and maximum level statistics, each separated by aircraft, road and rail traffic noise, for the respective year before the examination and for the participants of the Study on Health Risks even for the years 1996 to 2014. Of course, all data are anonymised according to the provisions of data privacy.

Road and rail traffic noise

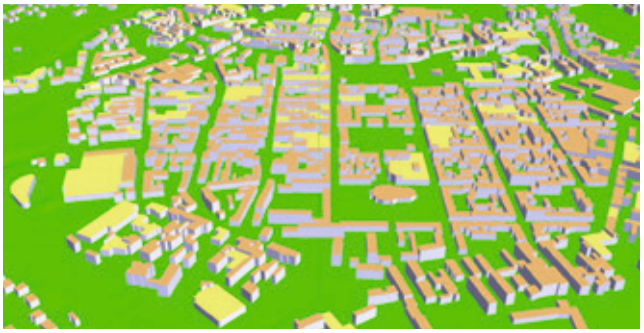
The data on road traffic noise are based on traffic counts of the state and the municipalities. Rail traffic noise data come from the Federal railway office and the Bahnumweltzentrum Berlin. Digital terrain models are used by NORAH to also consider obstacles in sound propagation – e.g. when a train line is behind a hill or building rows deflect noise.

Individual residential situation

The NORAH acousticians also considered information from the study participants on the floor or position of their bedroom in the deeper survey on the health situation. These factors may considerably influence how much noise actually reaches the study participant's ear.

For more information on the acoustics of the NORAH Study, see "NORAH Knowledge" no. 2.

3-D terrain models show where there are hills, valleys and buildings. The acoustic team used them to calculate how the rail and road traffic noise spread in the examined area.



Möhler + Partner AG

QUALITY ASSURANCE

Generally, it is not unusual to bring in external quality assurers for externally funded studies. NORAH went even further than many previous studies.

Internal quality assurance

The scientists of the NORAH Study subjected themselves to an internal quality assurance committee. Its members followed them in their work and reviewed the methods and results before they were submitted to the principal.

External quality assurance

The Scientific Advisory Board for Quality Assurance (WBQ) of the NORAH Study was independent of the researching scientists and reviewed their work in all steps. Two WBQ members each reported on one sub-study. The Öko-Institut – an independent environmental research institute – supported the quality assurance process. It advised the client of NORAH Study, the Gemeinnützige Umwelthaus GmbH, in scientific questions and acted as an interface between principal, scientific consortium and the WBQ.

For more information on the quality assurance of the NORAH Study see "NORAH Knowledge" no. 9.

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INTERVIEW WITH PROF. RAINER GUSKI, HEAD OF THE NORAH STUDY

Guski

PROF. RAINER GUSKI, head of the NORAH Study

There will be a lot of discussion on the NORAH Study. If you could choose: what should people talk about?

About the results, of course! Some were less surprising, such as the high annoyance effect of aircraft noise. Others were more so such as the strong connection between noise and depression. The negative influence of aircraft noise on children learning to read also had not been expected to be so clear. On the other hand, we see that there only is a trend in the connection between blood pressure and noise, where we expected a clear effect. We can discuss this now.

What do you think are some central insights?

There are important insights from all sub-studies. I think the annoyance results are essential. We originally thought that Frankfurt as a change airport had a very different annoyance than airports that have not been developed. This seems to be wrong. The annoyance in Cologne and Stuttgart also is much higher than ten years ago. The so-called aircraft noise standard curves of the EU are out of date. A second insight for me is that we cannot conduct the debate about noise and cardiovascular diseases as we used to. Before NORAH, everyone assumed that the risks clearly increased with the noise level because literature said so – even though it was never all that clear, if we look more precisely. Now we can see that the cardiovascular effects are less than reported. At the same time, another aspect that has hardly been examined before comes into focus: depression. Both will play a role in the scientific discussion. I'm sure of that.

Do you have any explanation of why annoyance by aircraft noise is rising not just in Frankfurt, but also at other airports?

Maybe the long-term energy equivalent noise level is no longer the right measure to predict aircraft noise effects. The total long-term energy equivalent noise level in the area of almost all German airports has dropped slightly. The number of flight movements, however, has increased. The long-term energy equivalent noise level does not seem to consider this.

Do the different traffic noise types have to be reassessed after NORAH?

Yes, at least aircraft and rail traffic noise. The latter seems less harmless today. We found the highest risks for cardiovascular diseases in rail traffic noise. The annoyance curve also does not correspond to the EU standard curve. This matches the results of the rail noise study in the Middle Rhine Valley, by the way. The annoyance from aircraft noise has increased in the last years. Both EU standard curves need to be revised. NORAH forms a good basis for this. For road traffic, we do not have as clear indications, but there are relatively few examinations that suggest a change.

Do you perceive the results as more reassuring or disconcerting?

Neither nor. The effect of noise has changed. It has not become "better" or "worse." I no longer see cardiovascular risks that are also discussed intensely in the region as being so extremely dangerous, at least regarding aircraft noise. All in all, the risks of aircraft noise have changed from physical effects towards psychological ones, and specifically depression.

What does this mean for residents?

Maybe we could put it like this: I can be less afraid of a heart attack, but I should know clearly that aircraft noise is a high psychological burden. Especially if I am psychologically sensitive, it may be harmful for me to live near the airport.

RESULT

The NORAH project was able to establish many exposure–effect relationships. These are curves that reflect the statistical connection between acoustic stress and the corresponding health effects. Individually they do not say anything about the numbers of "lost complaint-free years of life" or the traffic-noise-related heart attacks, as some publications calculate. However, they show us the statistically clear effects of traffic noise and the possible consequences of increasing exposure to noise. The strongest effect of noise is that the residents feel annoyed by it. This applied to all three traffic types at NORAH: most strongly to air traffic, followed at some distance by rail and road traffic. At a long-term energy equivalent aircraft noise level (glossary) exceeding 50 dB (glossary), the share of badly annoyed persons was between 40 and 55 percent, depending on the examined airport. In 2012, nearly 350,000 persons in the area of the Frankfurt airport were exposed to this noise level.

The Study on Health Risks, in contrast, showed that air traffic does not always hold the dominant role as cause of diseases. Depending on the area of disease, aircraft, rail and road traffic alternated. All three traffic noise sources bring statistically clear risks at least in specific groups or for specific diseases. In the Blood Pressure Study, no clinically relevant influence on blood pressure could be shown specifically for aircraft noise. When comparing the three noise types, it was noticed that aircraft noise had a special effect on the psychological level, and specifically on the annoyance and the risk of depression (glossary). The risk increase for cardiovascular diseases was partially stronger in rail and road traffic noise than in aircraft noise. The maximum noise level (glossary) at night may be more important in flight noise than the long-term energy equivalent noise level. In general, the authors conclude that the effects of all three traffic noise types have to be re-evaluated.

When comparing the three noise types, it was noticed that aircraft noise has a specific effect on the psychological level – specifically on the perceived disturbance and the risk of depression.

Glossary

You will find further explanations in the glossary at **www.laermstudie.de**.

Change effect

This term is used by noise researchers to describe the observation that people react differently to a change of noise exposure than would be expected based on the noise level. For example, they will feel more annoyed after an increase of the noise than others who have been consistently exposed to the same noise. The annoyance may even increase before the noise actually rises. On the other hand, people may feel overproportionally relieved when the noise reduces.

Long-term energy equivalent sound level

The long-term energy equivalent sound level (in short: L_{pAeq}) is a measure for the average noise exposure over a certain period in which frequency, duration and level of the individual sound events are taken into account. The L_{pAeq} is the basis for the determination of noise protection zones pursuant to the aviation noise act – separated according to day (6 a.m. – 10 p.m.) and night (10 p.m. – 6 a.m.). The L_{pAeq} is stated in dB.

Depression

Depression is a severe psychological problem in which affected persons suffer from sadness, lack of motivation and loss of interest. The acute phase of depression, i.e. the usually temporary occurrence of the disease, is called a depressive episode.

Decibel

The decibel – "dB" or "dB(A)" – is a measure of the sound pressure level and thus of the loudness. The decibel scale from 0 to 120 dB(A) reflects the range from the absolute threshold of hearing to the pain threshold. The scale is not linear. We perceive an increase of ten decibels as roughly a doubling of the loudness – at the lower and upper ends of the range.

Electrodes

An electrode is an electrically conductive object that, together with a counter-electrode, can conduct electrical currents in tissue located between the two electrodes into a meter.
In sleep examinations, electrodes are stuck to the body to measure, e.g., wake-up reactions.

Exposure–risk relationship

This relationship describes the connection between the noise a person is exposed to (exposure), and a specific risk. In some cases, such relationships are linear, so that it can be said, e.g., a noise increase of 10 dB increases the risk of heart attack by x percent.

Maximum noise level

The physical value which best describes how strongly nocturnal aviation noise impacts on sleep is the maximum noise level. It shows to what extent the aircraft noise stands out from the existing background noises. The annoyance effect overall depends on the height and the frequency of occurring maximum noise levels.

Sound level

This shortened expression generally refers to the sound pressure level, the physical value that describes the strength of the sound waves.

Significant / Significance

In statistics, we speak of a significant result when the effect is very unlikely (usually less than five percent) to be coincidental. Significance can be reviewed by statistical calculations.

Traffic noise

Traffic noise is the unwanted sound from cars, aircraft or trains.

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