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# Environmental assessments and wind parks - an empirical soundscape study

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# *Abstract*

Sound information is an increasingly important factor in people's interactive "experience" of daily life, including in the specific context of wind park projects. The literature on environmental impacts and regulations with respect to wind parks was reviewed and gaps in the research of the aural-visual impact of wind parks were identified. The relationship between soundscape and the underlying landscape in the context of wind parks was explored with the aid of simulated virtual scenarios.

The core findings of this dissertation are in three parts:

1) Perceived annoyance with aural and visual information of wind turbines within 500 meters was identical. Wind turbines may not obviously affect people's objective measures. The attitude to the sounds of wind turbines could be irrelevant to perceived annoyance.

2) The acoustical characteristics, i.e. sound pressure level and roughness, were strongly correlated with perceived wind park landscapes at a distance of more than 1 km. The ambient visual information may not change perceived annoyance about wind parks. The dominant sound sources have different effects on wind parks.

3) The aural-visual VR simulations developed on the smartphone were proven to be a valid method for the study of wind park soundscapes. "Diversity" of soundscape is one of the significant factors influencing the realism of the simulated virtual environment. The simulations can greatly enhance human perception of virtual geographic environment.

The findings of this dissertation could further our understanding of the impacts of wind parks, which could contribute to scientific suggestions and assist in the initial stage of wind park planning. Evaluating landscape change with a simulated virtual environment with aural information also has the potential to involve a wider variety of groups (residents, designers, planners and stakeholders) and encourage a broader range of inputs (i.e. multisensory) in the landscape planning and design.

# Zusammenfassung

Die Nutzung der Windenergie kann Treibhausgasemissionen reduzieren, zum Wirtschaftswachstum beitragen und die Energieversorgung sichern und diversifizieren. Windkraftanlagen sind in der öffentlichen Wahrnehmung jedoch nicht unproblematisch.

Die vorliegende Dissertation basiert auf einer sorgfältigen Literaturstudie zur Umweltwirkung von Windparks. Forschungslücken zur audio-visuellen Wahrnehmung von Windparklandschaften wurden identifiziert. Der Einfluss der Klanglandschaft auf Windkraftanlagen wurde mit Hilfe von simulierten virtuellen Szenarien untersucht. Die wissenschaftlichen Ergebnisse, als Hauptteil der Dissertation, lassen sich in drei Bereiche gliedern:

1) Die wahrgenommene Störung akustischer und visueller Aspekte verhält sich in ihrer Intensität im Umkreis von 500 m um die Windkraftanlagen proportional zueinander. Windräder können die untersuchten Maßstäbe der Menschen nicht signifikant beeinträchtigen. Die Einstellung zu den Geräuschen von Windkraftanlagen ist laut vorliegender Studie für die wahrgenommene Belästigung irrelevant.

2) Die akustischen Eigenschaften (Schalldruckpegel und die Rauhigkeit) sind stark mit wahrgenommenen Windparklandschaften korreliert. „Entspannung“ und „Natürlichkeit“ der Klanglandschaft sind die Schlüsselfaktoren, die die wahrgenommene Störung beeinflussen. Daneben ist die dominierenden Schallquelle ein wesentliches Kriterium.

3) Die auf dem Smartphone entwickelten audio-visuellen VR-Simulationen haben sich als valide Methode zur Untersuchung von Klanglandschaften erwiesen. „Vielfalt“ der Klanglandschaft ist einer der wesentlichen Faktoren, die den Realismus des simulierten virtuellen Raums beeinflussen. Die Simulationen könnten die menschliche Wahrnehmung des virtuellen geografischen Raums erheblich verbessern.

Die Ergebnisse dieser Dissertation unterstützen unser Verständnis der Wahrnehmung der Auswirkungen von Windkraftanlagen auf die Landschaft. Die Bewertung von Landschaftsveränderungen über den simulierten virtuellen Raum gekoppelt mit akustischen Informationen bietet die Möglichkeit, eine größere Vielfalt von Gruppen (Einwohner, Planer, Investoren und Stakeholder) in Entscheidungsprozesse einzubeziehen und dadurch konsenzfähige Entscheidungen zu treffen.

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# Contents

# Chapter 1

# Introduction

## 1.1 The rising energy consumptions and demand for wind energy

With the development of the economy and technology, the demand for energy resources is increasing significantly. China is amongst the leading energy consumers in the world, while Germany has the largest energy market in Europe and is its leader in shifting to renewable sources of energy. Therefore, in the following discussion, we take examples from these two countries of energy demand and energy strategies, to gain a better understanding of the development of wind energy.

According to the International Energy Outlook 2016, total world consumption of energy expands from 527.9 quadrillion British thermal units (Btu) in 2010, to 628.9 quadrillion Btu in 2020, and to 815 quadrillion Btu in 2040 - a total increase of 54% from 2012 to 2040 (GWEC, 2016; Torp and Heinrich, 2016; Ziesing, 2017) (Figure 1.1). Over the same period, energy consumption in China will increase by 65.3% and in Germany will decrease by 32.3%. As the main threats to human society, climate change and global warming are often linked with energy consumption and greenhouse gas emissions (Nejat et al., 2015). Two-thirds of worldwide $CO_2$ emissions are believed to be produced by ten countries: China, the US, India, Russia, Japan, Germany, South Korea, Canada, Iran, and the UK. The effect of increasing greenhouse gas emissions has reached a new high by raising global average surface temperatures by $3°C$ to $4°C$ within this century (Allison et al., 2014). Therefore, the rapid development of large-scale, low-carbon renewable energy sources is required in order

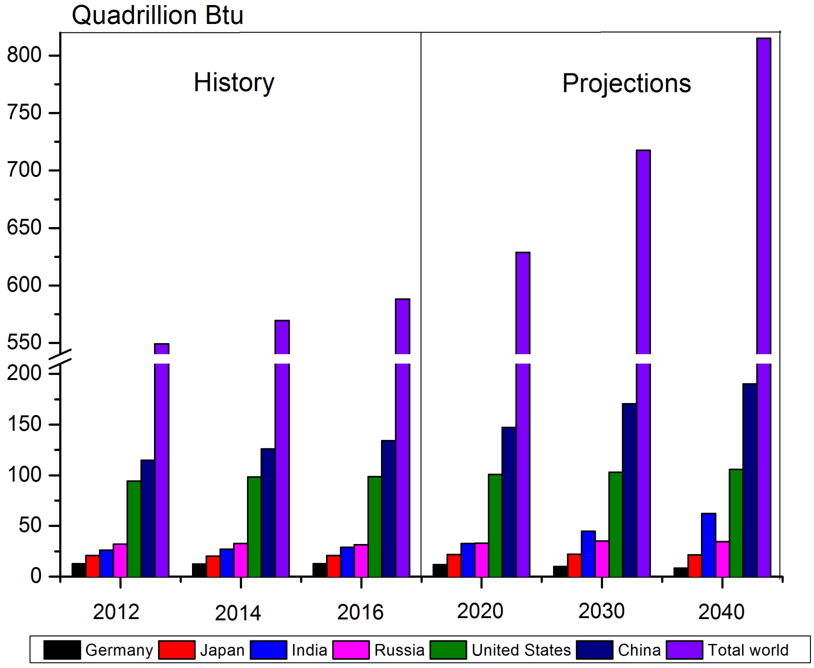


FIGURE 1.1: Energy consumption in selected countries and worldwide (GWEC, 2016; Torp and Heinrich, 2016; Ziesing, 2017).

to reduce the global warming effects, which can lead to extinction risk for numerous species and threaten world ecosystems. Thus, energy policies in these countries play a significant role in impacting the world environment.

Energy consumption and $CO_2$ emissions in Germany have shown a promising downward trend. However, developing countries, such as China, are still taking urbanization and economic growth as their main driving factors. $CO_2$ gas emissions and energy consumption have been increasing in the past and will continue to rise for some time in the future (Figure 1.1).

There are growing concerns about finding suitable energy-saving strategies, technologies and energy sources. In this context, wind energy has been suggested as the main way of meeting future energy demand and reducing $CO_2$ gas emissions. Wind energy industries, markets and policy frameworks have been developed rapidly in recent decades, and governments across the world have assigned priorities to develop wind energy. Total worldwide installations in 2015 were more than 43,3 GW, dominated by the top ten countries including China, the US, Germany, India, Spain,

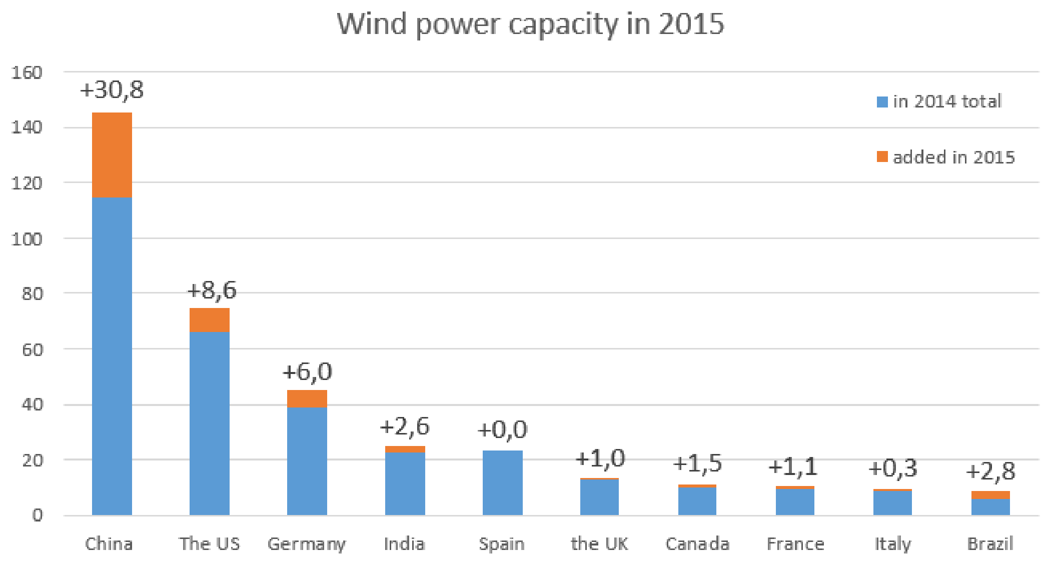


FIGURE 1.2: Top ten countries in terms of wind power capacity in 2015 (Unit: GW).(GWEC, 2015)

the UK, Canada, France, Italy and Brazil (GWEC, 2015). Since 2004, wind power capacity in China has increased dramatically thanks to a positive and supportive wind energy policy. China reached first place in the world in terms of total capacity by the end of 2010 (Wu et al., 2014).

Figure 1.2 shows the total installed wind power capacity in 2015 in the top ten countries (Figure 1.2). China led a new record with an additional 30,8 GW capacity in 2015, followed by the US (8,6 GW) in terms of annual installations. Germany came in third with 6 GW of new capacity and remains the country with the largest installed wind power capacity in Europe. There was a lot of activity in 2015 around the world, and the installation of wind turbines reached a broader distribution. In Germany in particular, capacity accounted for 44% of total EU wind energy installations (Mbistrova and Nghiem, 2017), reflecting the strength of Germany's wind energy market and the stability of the regulatory framework.

## 1.2 Environmental challenges in the development of wind energy

Wind energy represents one of the most important renewable resources. Sustainable utilization of wind energy can reduce greenhouse gas emissions, contribute to economic growth, and secure and diversify the supply of energy. It does not pollute the air like other sources of energy including gas or fossil fuel. Wind energy has been identified as one of the cleanest energy sources and contributes to a low carbon energy system in displacing fossil fuels. However, development of wind energy still has a mild impact on the environment. In particular, wind turbines can have negative influences on the social and ecological environment.

The installation of wind turbines can change land or seascapes and cause light and noise emissions. They modify the image of the landscape, are often visible from far away and do not fit into every landscape. On closer inspection, they frequently encounter public resistance, as they are viewed as visual and audible intruders that spoil the landscape and generate noise (Leibenath and Otto, 2013; Möller, 2006). The effects of wind turbines on birds and wildlife could lead to a conflict between renewable energy generation and biodiversity conservation goals, which are mentioned in earlier studies. These human and environmental impacts have been deemed less important compared to impacts such as gas emissions produced by other energy sources. Before any decision is made, the worst condition has to be determined and predicted; the potential negative impacts of wind parks are described in detail below.

### 1.2.1 Visual impact

The development of wind energy will modify landscape settings and cause land or seascape change, due to wind turbines being huge technical constructions. The installation sites are usually in open fields or on the tops of hills or mountains; the consequence of their special need for wind speed is that they are visible even from a very long distance. The related transportation network also affects the landscape significantly.

It is mostly the social environment that could be impacted by wind parks; the subjective impacts depend on the target group and often vary from region to region. People may view wind turbines as clean and meaningful constructions when they are "not in my backyard"; otherwise, wind turbines may be considered as ugly and annoying constructions which convert natural, recreational area into industrial sites. The assessment of the visual impact of wind parks is not usually given as much attention as wildlife and land protection. The methodologies for the assessment of visual impact are mostly based on a geographical information system (GIS). During the planning process of a wind park, GIS and viewshed mapping can help determine the visible areas of wind parks and the potential degree of the visual impact.

It is still considered difficult to evaluate the visual impact of a wind park, and the indicator system currently used is incomplete (Katsaprakakis, 2012; Sibille et al., 2009). In order to understand the landscape in an area with projected wind parks, and ensure the visual amenity, it is important to establish the visible area and the viewpoints from which people can experience the views.

#### 1.2.1.1 Visibility and color

Visibility and color were the characteristics that were most mentioned in connection with the visual impact of wind parks. In the planning for wind parks, visual coordination was determined as the major factor in influencing the location selection (Sibille et al., 2009; Yeh and Huang, 2014). Viewsheds are commonly used to determine the visibility of a projected wind park and to identify visible areas that are important to the public. These areas are also known as Zones of Visual Influence (ZVI), Zones of Theoretical Visibility (ZTV) or Visual Exposure Zones (VEZ). Visibility maps for every place of interests, such as settlements, archaeological sites and sites with special scenery, were suggested to be calculated. Through the viewshed function, the visibility of each map cell in a zone with radius 10,000 $m$ surrounding the special areas based on digital elevation model (DEM) could be created.

The working process is presented below (Fig. 1.3). Generation of visibility maps is an initial step in the planning process for wind park sitting selection. However, the process fails to include numerous details, and this could lead to misclassification. For example, viewsheds fail to consider intervening buildings, trees and other high structures. Large wind turbines that are higher than the calculated average height

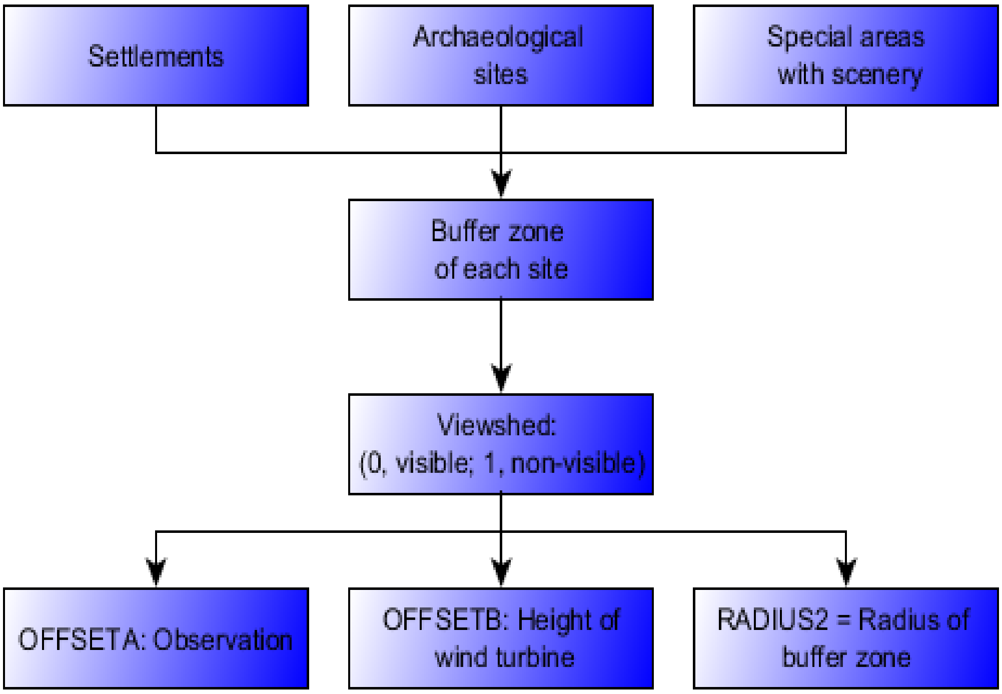


FIGURE 1.3: Working process of generation on visibility maps (Tegou et al., 2010).

can be visible for 1 km or more than shown in the simulated situation (Gibbons, 2015).

Visibility of wind turbines was supposed to have a negative impact on local house prices. The price impact was about 6.5% if the distance to a visible wind park was within 1 *km* (Gibbons, 2015). Within 2 *km*, the price reduction is 5.5 - 6%, falling to 2.5 - 3% within 4 *km*. The house price reduction was below 1% beyond 4 *km* and becomes of no significant impact for further distances (Table 1.1).

Color is one of the determining factors in impacting visual perceptions of wind turbines. The greater the contrast of the color of wind turbines with the background color, the greater is the impact. It is important for the color of the wind turbines to merge with the surroundings' color. Usually, white and light gray tones of both the turbine's blades and tower are preferred, to match the color of the cloudy sky. For the bottom of a turbine, a gradual transition from green (close to the bottom) to white has been developed (Katsaprakakis, 2012; Sibille et al., 2009). Matt-coated blades are generally used on the outer turbine to reduce reflection. In addition, wind

TABLE 1.1: The house price effects by operational wind park within 14 *km* (Gibbons, 2015).

| Distance to a visible wind park | House price reduction (%) |
|---|---|
| **Within 1** *km* | 6.5 |
| **1 - 2** *km* | 5.5 - 6 |
| **2 - 4** *km* | 2.5 - 3 |
| **Beyond 4** *km* | $< 1$ |
| **8 - 14** *km* | $\approx 0$ |

TABLE 1.2: Suggested minimum distance to wind constructions (Latinopoulos and Kechagia, 2015).

| Categories | Minimum distance to wind turbines |
|---|---|
| **Protected landscapes** | 1000 *m* |
| **Historical and archeological sites** | 1000 *m* |
| **Settlements** | [Population > 2000 inhabitants]: 1000 *m*<br>[Population < 2000 inhabitants]: 500 *m*<br>[Traditional settlements]: 1500 *m* |
| **Tourists areas** | 1000 *m* |

turbines are built with a tubular tower with visual uniformity, rather than a lattice, for better public acceptance.

#### 1.2.1.2 Distance

In order to avoid visual impact, wind parks were limited to being built far from settlements, historical sites and places of interest. The visual effect declined sharply as the distance to wind turbines increased (Fig.1.4). At distances greater than 5 *km*, the wind turbine gradually merges with its surroundings and was considered to be of no harm aesthetically.

Areas which are far away from settlements or places of interest are generally reasonable for gaining public acceptance (Höfer et al., 2016). Considering the visual impact, the distance for wind park building to urban areas mostly ranges between 1000 *m* and 1500 *m* according to local regulation. The suggested restricted distances to wind parks in different categories are listed below in terms of visual impact (Table 1.2) .

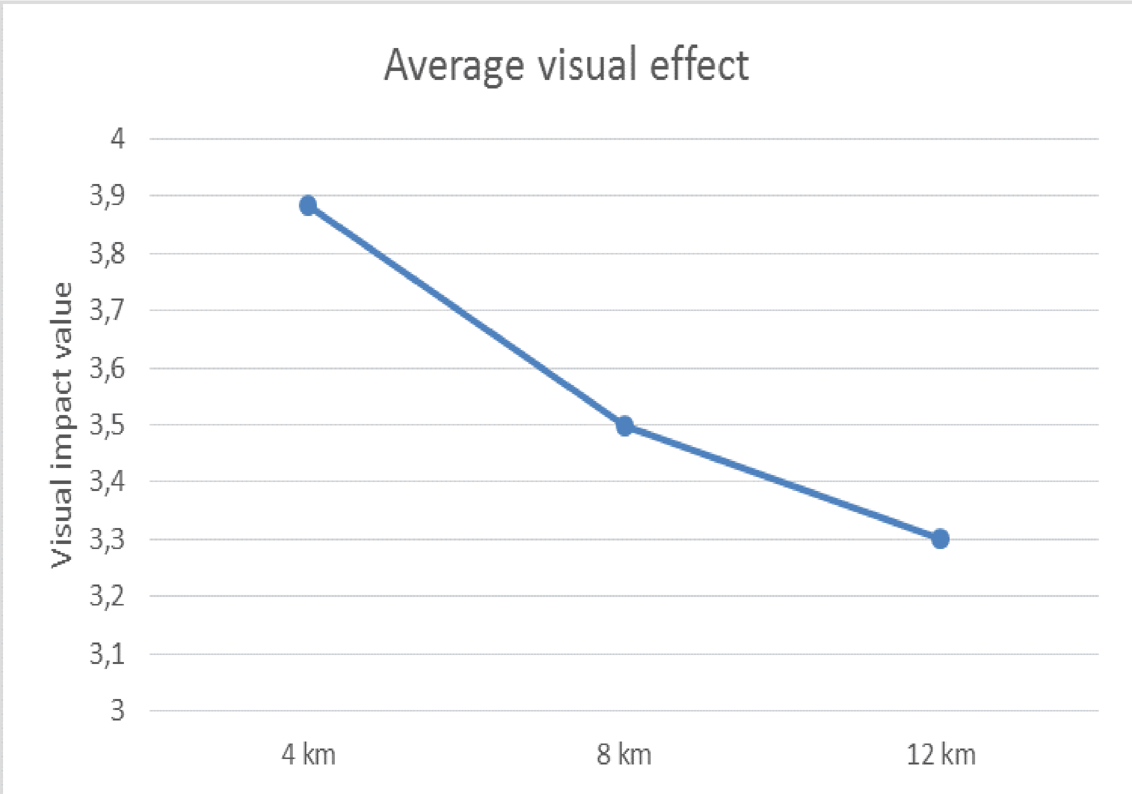


FIGURE 1.4: Decline in visual impact value (scale 1-5) of offshore wind turbines with distance (*km*). The value 3 is a neutral response (Bishop and Miller, 2007).

#### 1.2.1.3 Turbine blades movement

The visual impact is dependent on the effect of blade movement. It was found that movement of the turbine blades was considered as the second major factor influencing aesthetic ratings (Bishop and Miller, 2007). The negative visual effect was higher in the case of stationary blades than moving ones, particularly when wind parks are close. When wind turbines are in normal operation, they are considered as useful for society, and so they can be accepted visually. In contrast, if wind turbines in a wind park are not in operation and are still, the impression of usefulness was produced and this leads to a negative visual impression by observers (Katsaprakakis, 2012).

#### 1.2.1.4 Shadow flicker

Shadow flicker is caused by rotating turbine blades casting shadows on the ground and nearby homes when the sun appears. Settlements nearby may suffer from very low angle sunlight, and the most annoying part is the visibility of an intermittent light reduction when at home, for instance, in the kitchen facing the wind turbines.

It is possible to reduce the shadow flicker effects, if there are obstacles, such as trees or constructions between the wind turbine and a likely shadow flicker receptor. However, in rural settings, the areas are often large and people often work outside or engage in outdoor recreation. Thus, the presence of shadow flicker creates a significant environmental nuisance. Also, a 45 $m$-high turbine will cast distinct shadows for thousands of meters (Knopper and Ollson, 2011; Bolton, 2007; Saidur et al., 2011).

During sunset or sunrise, flicker shadows are particularly long. With the increase in the height of turbines, the shadow flicker effects get worse. There is a need to reduce the shadow flicker effects for sustainable wind energy usage. In the regulations, the allowed shadow flickering during the year is listed in the table (Table 1.3).

In the shadow flicker analysis, computer models can determine the effects of shadow flicker on settlements, such as the number of hours of shadow flickering. The maximal minutes of shadow flickering on the worst day and the number of days of shadow flickering per year are calculated. Through the appropriate selection of

TABLE 1.3: Maximal time allowed by Shadow flickering effects (LAI, 2002)

| Condition | Time restriction |
|---|---|
| **Worst case: no clouds effects** | Maximal 30 hours per year |
| **On worst day** | Maximal 30 minutes on the worst day |
| **Real case: clouds and visibility effects included** | Maximal 8 hours per year |

the wind park's installation site, further steps can be taken, such as the turbines can be shut down to avoid shadow flickering effects on the worst days.

### 1.2.2 Noise emissions

Another primary environmental issue related to wind power usage is noise. People living close to wind parks will be affected by the noise factor. It was reported that residents near to wind parks suffer health effects related to noise (Bakker et al., 2012), including audible noise and inaudible noise. Audible noise and infrasound were found to correlate with epilepsy, sleep disturbance and cognitive disruptions as well as stress and anxiety (Knopper and Ollson, 2011).

The noise of wind turbines was generally characterized as swishing, whistling, resounding and pulsating/throbbing by people who noticed the noise. People who notice these sounds from wind turbines can get annoyed by them; these people perceive the sound as being louder than do other people who are neighbors of wind turbines. In addition, statistically, it was shown that sound pressure levels were the factor most closely related to wind turbine noise annoyance (Pedersen and Waye, 2004).

The noise emitted from a wind turbine can be decomposed into mechanical noise and aerodynamic noise. The mechanical noise is due to the rotating machinery of the wind turbine. The aerodynamic noise is generated because some of the kinetic energy turns into noise and heat; conversion of kinetic energy from the wind into mechanical energy is not 100% efficient (Table 1.4). The noise from modern wind turbines has been reduced, with less than 10% related emissions since the 1980s, due to improvements in blades' aerodynamic design (Burton et al., 2001).

TABLE 1.4: Type of noise produced by wind turbines

| Category | Generation | Influence factor | Other influence factors |
|---|---|---|---|
| **Aerodynamic noise** | Low frequency noise (changes in the wind speed experienced by the blades), Interaction of blades with the atmospheric turbulence and by the airflow along the airfoil surface. | Turbine size, wind speed,blade rotation speed. | Air temperature, humidity, barriers, reflections and ground surface materials; Background noise. |
| **Mechanical noise** | From rotating machinery of wind turbine (internal gear box, the generator, cooling fans, auxiliary parts and the yaw system). | Insulation during manufacturing (design and machining of the gearbox, use of anti-vibration mountings, couplings, acoustic damping of the nacelle and liquid cooling of the generator). | |

TABLE 1.5: Examples of audible noise level (Burton et al., 2001).

| Condition | Sound pressure level ($dBA$) |
|---|---|
| **Rural night time** | 20 - 40 |
| **Single turbine at 500 $m$** | 25 - 35 |
| **10 turbines at 500 $m$** | 35 - 40 |
| **Single turbine at 40 $m$** | 50 - 60 |
| **Human speech** | 60 |
| **Night club** | 100 |
| **Modern wind turbine** | 90 -105 |

TABLE 1.6: Estimates of annually bird mortality in the U.S. (Drewitt and Langston, 2006).

| Region | Estimated bird mortality | Mortality per turbine | Mortality per $MW$ |
|---|---|---|---|
| **California** | 108.715 | 7.85 | 18.76 |
| **East** | 44.006 | 6.86 | 3.86 |
| **West** | 27.177 | 4.72 | 2.83 |
| **Great plains** | 54.115 | 2.92 | 1.81 |
| **U.S.** | 234.012 | 5,25 | 4,12 |

Table 1.5 gives an indication of the typical audible noise level. The noise level from modern wind turbines ranges from 90 - 105 $dBA$ as perceived by the human ear. The noise level reduces as the distance to the wind turbine increases; a single turbine at the distance of 40 meters causes sound pressure levels of 50 - 60 $dBA$. Moreover, it was found that house price reductions within 2 $km$ of wind farms, where turbines are not visible, may be related to wind park noise (Bishop and Miller, 2007).

Noise impact assessments should be conducted. Appropriate distances should be kept between wind turbines and sensitive receptors during wind park siting procedures to avoid noise nuisance. A minimum setback distance to wind turbines has been established worldwide for mitigating wind park noise annoyance. Permitted noise exposures and recommended practices have been developed by national regulations or standards, such as the Occupational Safety and Health Administration Standards (OSHA), and the International Energy Agency (IEA).

TABLE 1.7: Top ten fatality species due to wind turbines (Loss et al., 2013; Grünkorn et al.; Song et al., 2011).

| Germany | California, USA | Jiangsu Dafeng, China |
|---|---|---|
| Common Buzzard | Red-tailed hawk | dunlin |
| Red Kite | Rock dove | Red-necked stint |
| White-tailed Eagle | Western meadowlark | spotted redshank |
| Mallard | Burrowing owl | common stilt |
| Swift | European starling | Great knot |
| Black-headed Gull | American kestrel | black-collared starling |
| Wood Pigeon | Golden eagle | Common redshank |
| Skylark | Barn owl | Common sandpiper |
| Herring Gull | Mallard | White wagtail |
| Starling | Mourning dove | Chestnut bunting |

### 1.2.3 Impacts on birds and wildlife

Wind turbines are sited in open, exposed areas with high average wind speeds, which often provide vital habitats for birds and wildlife. Concerns about collisions of birds with wind turbines in the USA and habitat loss in Europe has increased significantly since the 1990s (Burton et al., 2001). It was reported that annually 0.01 - 23 $birds/turbine$ collide with turbines' spinning blades (Drewitt and Langston, 2006). Though more birds are killed by other man-made constructions such as nuclear plants, fossil fuel plants and the windows of buildings. The average mortality per turbine is only 4.12 (Table 1.6), though the potential disturbance to birds and wildlife and especially the threat to endangered species by wind turbines is still an issue across countries where the turbines are near wild habitats (Loss et al., 2013; Sovacool, 2013).

The habitats surrounding wind parks differs from region to region and from country to country. In the above table, the top ten fatalities by species for Germany, USA and China are summarized (Table 1.7).

A preliminary investigation of the siting location is therefore not only important, but also very helpful in mitigating the potential biodiversity loss. The impact of a wind turbine on birds and wildlife can be concluded in the following ways:
1) Collision with the blades,
2) Displacement of birds and habitat due to disturbance,


FIGURE 1.5: Birds and wildlife under wind parks (a) Tortoise lived under wind turbines; (b) birds collision with wind turbines; (c) thermal infrared image of the process of a bat being collided by a blade (Lovich and Ennen, 2013; Horn et al., 2008; Loss et al., 2013).

3) Barrier effect where a wind park creates obstacles in the breeding colony and migration corridors,
4) Habitat disturbance and loss.

The impact on birds and wildlife is highly variable and influenced by many factors including the surrounding habitats, the topography, the layout of wind parks, the technology of turbines, the number and species of birds nearby and the weather. Thus, a smart micro-siting design for wind park projects shall be conducted individually (Wang and Wang, 2015). The main negative impact of wind parks are on volant wildlife through aerial and barotrauma impacts. (Dai et al., 2015) summarized that bird mortality caused by wind turbines and the number of bird mortality incidents varied due to different factors, such as wind turbine design and siting location of the wind park. Investigation of the occurrence of birds in space and time and their behaviors before the site planning for a wind park was suggested (Hüppop et al., 2006).

There are also many negative impacts on non-volant wildlife. It was reported that richness of vertebrate species declined due to construction and decommissioning of wind turbines. The number of tortoises living in and around the wind parks declined, based on the study of Lovich (Lovich and Ennen, 2013). Indirect effects of wind turbines on the mortality of tortoise were found, due to car crushing on an access road to wind turbines, ground erosion in terms of construction of wind turbines and entrapment in a culvert associated with turbine infrastructure (Fig. 1.5).

Siting areas of wind parks with low bird and raptor use was suggested as the best way to mitigate collision mortality (Erickson et al.). Keeping a distance from the most abundant habitats may also contribute to minimizing the negative impact on birds and wildlife. Maintaining a distance of at least 300 $m$ from any nature conservation area was suggested. The monitoring and modeling were proposed as an efficient methodology to design a suitable wind park area. Bird flight activities including flight heights, directions, species and behaviors need to be analyzed systematically within a buffer of 200 to 500 $m$ around a planned wind park (Dai et al., 2015). New techniques with a program to stop the operation of a wind turbine were applied and proved to be efficient in mitigating 50% of the avian mortality with little reduction of energy production (de Lucas et al., 2012). In addition, optimization of the design of turbines was considered as a useful way of reducing bat mortality. For example, increasing turbine blade width, number of blades, rotational velocity and operational wind speeds of 6 $ms^{-1}$ were suggested (Long et al., 2010).

### 1.2.4 Occupation of land

The building of wind parks needs land before, during and after the construction of the wind turbines. The area of land for wind park construction requires around 200 - 300 times less than thermal power plants of the same nominal power (Canale et al., 2009; Katsaprakakis, 2012). However, the amount of land required is still large, and the negative impact of the occupation of land can be seen in the construction of wind turbines. Installing a 3 $MW$ wind turbine needs a 1600 $m^2$ land area. The activities related to wind parks include setting up the site compound, manufacturing the foundations (concreted in situ and after excavation) and constructing roads for access, all of which, could lead to negative impacts on land (Fig. 1.6). The construction procedures are detailed below:

a) Preparing the construction site
Before the construction of a wind turbine, the site needs to be cleared and the access built. The roads provide access for turbine equipment for construction and facilitate access to the installed turbine for later operation and maintenance. At the same time, the land is graded and the pad area is leveled around the projected wind turbine (Fig. 1.6.a).

b) Foundation placement
Foundations are concreted into the excavated hole and mixed with reinforcing steel.


FIGURE 1.6: Activities of construction of a wind turbine (a. road construction, b. foundation placement, c. turbine erection).

The excavated topsoil and subsoils are then backfilled over the outer circle of the concrete foundation (Fig. 1.6.b).

c) Turbine erection
The components of each tower section are set progressively. The nacelle of the turbine is erected at the top of the tower and can be reached by a ladder inside the tower. Then three blades are connected to the hub and assembled on the nacelle at the top of the tower (Fig. 1.6.c).

During the construction period, the land cover around the turbine can be modified a lot. Soil erosion may occur due to the loss of green surface cover, and soil pollution caused by waste water and oil from the wind turbines may be evident. These issues can have possible negative impacts on the surrounding ecosystem. It was suggested that a measure of the recovery of the local environment should be conducted after the construction of wind parks (Dai et al., 2015).

### 1.2.5 Electromagnetic interference of wind turbines

Wind turbines have the potential to cause electromagnetic interference (EMI) mainly from the moving blades. Factors including near-field effects, the diffraction in the Fresnel zone and reflection or scattering effects were found in degradation of radio performance. Among these factors, diffraction effects and reflection or scattering effects were the main one affecting the signal waves (Katsaprakakis, 2012).

Wind parks can be obstacles affecting the signal transmission of nearby radio or television stations. Many electromagnetic systems such as televisions, FM broadcast radios, microwave communication systems, and navigational systems could thus suffer interference (Dai et al., 2015).

Due to the new synthetic materials that are used instead of metal blades, the reflection influence may not now be all that strong. Though the EMI produced by the wind turbine itself is exceptionally weak and is limited to a small range, the EMI could interfere with the perception in receptors for flying animals, especially bats which could be struck and killed by the turning rotor blades. Furthermore, the rotating blades could reflect the radar signals, thus increasing flight radar interference, affecting flight safety and homeland air security. According to German local legislation, the minimum distances to the telecommunications and radio or television stations should be maintained to the EMI. With proper and scientific design, the EMI caused by wind turbines can be reduced to close to zero.

### 1.2.6 Regulations concerning wind park projects

As described above, wind turbines can produce noise and cause shadow flicker effects. The turbines can be visible from a very long distance and may not be in harmony with the surrounding landscape. Wind park projects are normally not allowed in the vicinity of residential, industrial or commercial regions. Also, wind parks could convert natural, recreational sites into industrial areas. In the regulatory approval process, the wind park project should be assessed according to the local regulations. To better understand these regulations, the most important regulations involved in the planning of wind parks in Germany, Mecklenburg-Vorpommern, are detailed below (PVRR, 2012).

The Renewable Energy Law (Erneuerbare-Energien-Gesetz, EEG) forms the basis for the usage of renewable energy sources for electricity generation (EEG, 2014). It encompasses the operation of wind parks and their connection with the power grid. The grid operators are obligated to pay fees for electricity generated by wind turbines. The fees are set at regular intervals until environmental friendly power generation could economically self-sustaining and competitive with electricity produced from conventional power plants.

The Spatial Planning Act (Raumordnungsgesetz, ROG) regulates the preparations of regional plans, which are the large-scales plans for the whole federal states or their subspaces (ROG, 2008). The ordinary citizen is seldom involved in this planning, as most related specifications are very abstract. Generally, they are kept inclusive and unclear, and so individual property owners may not even realize to what extent they will be affected. In the case of wind turbines, the regional spatial plans can be crucial, as priority areas have been planned specifically for these facilities. In the priority areas, wind parks can be approved and installed without the need for more detailed planning at the community level.

While the laws described above are valid for the whole of Germany, State Planning Act M-V is the regulation for the state of Mecklenburg-Vorpommern (LPlG, 2011). The State Planning Act M-V Law regulated in principle the same as the Spatial Planning Act (ROG), but in more detail. It defines, for example, which authorities are involved in spatial planning and what procedures for planning need to be followed.

The Federal Building Code (Baugesetzbuch, BauGB) is also a federal law, and it covers everything related to the planning and building in the communities that are regulated (BImSchG, 2013). It includes rules for the preparation of land use plans and development plans. For wind parks, paragraph 35 is decisive, as it regulates free installation outdoors and beyond the areas of the planning scheme, and principally in certain areas installation is only permitted in the planned areas for wind turbines.

The Federal Emission Control Act (Bundes-Immissionsschutzgesetz, BImSchG) aims to protect people from health risks from noise, pollutants and other environmental effects caused by technical constructions. Each wind turbine higher than 50 $m$ needs to be approved according to the regulations of BImSchG. Some key indicators need to be measured, i.e. the noise and shadow flicker. Related distance should be maintained.

The Federal Nature Conservation Act (Bundesnaturschutzgesetz, BNatSchG) regulates aspects of landscape planning and defines natural and landscape protective areas (BNatSchG, 2009). Within these areas, construction of wind parks is not allowed. For the habitat of animal species at risk of extinction, the installation of wind turbines is strictly limited. The aim of this act is to protect the endangered species from disturbance and being driven away. Thus, in the planning of wind turbines, birds and bats need to be paid attention. Another important rule is the intervention regulation, which states that any intervention in natural and landscape areas must be recovered. Anyone who builds a new wind turbine that changes the landscape must take compensating measures to improve the landscape, i.e. planting trees.

The Environmental Impact Assessment Act (Gesetz über die Umweltverträglichkeitsprüfung, UVPG) originally comes from European Law (UVPG, 2010). It requires that all major planning and construction projects must investigate environmental impacts. This process already starts at the spatial planning level, when the areas for wind parks are selected. It is mandatory in the subsequent approval procedure, when a wind park has 20 or more wind turbines. All results must be publicized for the community, so that all citizens can have the opportunity to respond.

Therefore, according to these criteria, many locations are out of consideration for wind park projects. These parks need to keep a set distance from residential areas and be away from nature reserves and the routes of migratory birds. To prevent potential disturbances and annoyance by wind parks from the outset, wind park projects should be investigated right at the beginning of the planning. Only after careful examination using these criteria, can suitable sites for wind parks be selected. In practice, the standard limitations can be summarized as follows for wind park projects in Mecklenburg-Vorpommern:

**Locations**

a) Areas which serve as recreation, tourism and health (residential, mix and rural areas, special areas), inclusive 1000 *m* safety distance.
b) Detached houses and split settlements in the outside spaces include a protective distance of 800 *m*.

**Priority areas**

a) Priority areas for nature conservation and landscape management.
b) Priority areas for the securing of raw materials.
c) Priority areas for trading and industries.

**Areas with high degree of protection**

a) Areas with very high protection of the free space function.
b) Areas with very high protection of the landscape image.

**Forests and water body**

a) Forest areas bigger than 10 *ha*.
b) Inland water bigger than 10 *ha*.

**Protected areas and protected biotopes**

a) Legally protected biotopes bigger than 5 *ha*.
b) Natural parks.
c) European bird protected areas.

When the question is what kind of landscape is considered beautiful or meaningful or has special significance to human beings, there is still a lack of specific planning regulations. Many wind energy controversies are relevant to the image of the wind parks on the landscape. People may find the wind turbines ugly and disturbing for our landscape. However, the landscape has always been changing due to human use in recent centuries. Even highways, industrial plants and large residential and commercial buildings do not fit into our traditional ideal of a harmonious cultural landscape, yet nowadays they are a part of our landscape. Slowly, some wind parks are becoming part of the normal landscape, and most residents or tourists can accept them. However, wind parks should not completely dominate our landscape in the future, especially in a tourist region, such as Rostock. Here, most accepted wind parks to be constructed are small to medium size and, in the coastal areas, wind parks are totally forbidden. To avoid undesirable developments, research should be conducted to investigate the particularly valuable landscape spaces and give scientifically-based suggestions for landscape planners and politicians. Therefore, in the following, the main goals related to these suggestions are demonstrated.

## 1.3 Overall goals and research design

Previous studies highlighted the importance of determining and evaluating perceptions toward wind park landscapes (Molina-Ruiz et al., 2011; Sibille et al., 2009). As wind turbines are built higher and bigger, wind park landscapes have poorer integration into the local landscape. There is a requirement for a preliminary environmental impact assessment as regards to local legislation in order to minimize the interference from wind park construction on the landscape. However, there is still a lack of comprehensive understanding of the effects of wind parks on landscapes.

Wind power is contributing to an environmentally-friendly energy supply, as only the land space for the wind parks is available. Effective political systems and regulatory frameworks are key to promoting the development of renewable energy, including wind energy, with the purpose of reducing $CO_2$ emissions in the long-term. German wind energy policy has taken significant steps toward stimulating the use of low-carbon energy sources.

The European countries have limited land space for the construction of wind parks, especially in Germany. Planning authorities are moving toward limiting locally-available places by designating "Eignungsgebiet" which means "priority areas"; planned wind park projects can only be allowed within those priority areas (Ohl and Eichhorn, 2010). In the Rostock region, the priority areas for wind turbines comprise about 1% of the total land area of the region (PVRR, 2012).

One of the aims of this PhD thesis is to assess the impact of wind parks, evaluating the affective and cognitive functions and investigating individuals' responses to wind parks. In order to answer the research questions, investigations were designed using virtual reality (VR) technology. Scenarios were created to assess a landscape without wind parks and the same landscape with the projected wind parks. In each scenario, individuals rated their noise and visual annoyance, and their cognitive functioning test combined short-term verbal memory and executive control. This research project is presented in Chapter 2.

The major aim of this study project was to develop a methodology to predict and evaluate the aural-visual impact of wind parks, taking the aural information from different investigation sites into account. Surveys were thus conducted to characterize different soundscapes ambient to wind parks. An evaluation method of semantic differential technique was adopted for the landscape study. This study could help to determine and evaluate the proper sites for new wind park projects. Research questions involved effects of sound levels, visual information and perception in multidimensional indices related to wind parks. These research questions are addressed in Chapter 3. Within this chapter the relationship between the soundscape and wind parks has been outlined. It also presents a critical analysis of the barriers faced by the landscape planning sector.

The final aim of this PhD thesis was to minimize the perceived annoyance toward wind parks through public participation with the aid of VR technology. In this research project, the validity of VR technology for the study of wind park soundscapes was assessed. The acceptance and perceived annoyance from wind parks at different sites, the realism of the audio-visual simulation method, and how the aural and visual information influence the realism were investigated. These final research questions are addressed in Chapter 4.

## 1.4 Outline of the thesis

This PhD thesis investigates individuals' responses to visual landscapes, sounds ambient to wind park, and the interactions of these two modalities within the context of wind park design and planning. While confirming the importance of other sense modalities on the perception of wind park landscape, this research project is limited in comparing visual-aural interactions. A cross-platform game engine, Unity 3D, was used to build visual stimuli of the wind parks for mobile devices. On-site recorded sounds were used for our tests, though it is acknowledged that surveys on different types of sounds such as synthesized sound are also needed.

The thesis is divided into five chapters. Chapter 2 to Chapter 4 contain finished manuscripts which have been published or have been submitted for publication in peer-reviewed journals. These chapters comprise the core part of the whole thesis and summarize the main contributions as regards the overall goals and the research questions. Chapter 1 and Chapter 5 review the core part of the thesis. Chapter 1 introduces the research background for wind energy and demonstrates environmental impact as regards wind parks, while Chapter 5 summarizes overall conclusions and the contributions of this study project. A brief description of each chapter is as follows:

Chapter 1 first introduces the need for energy consumption and thus demand for wind energy due to its environmentally-friendly resources. In addition, the potential environmental challenges for wind energy construction are addressed. Then, the overall environmental impacts of wind parks and the relevant regulations are summarized. Last, the overall goals and research designs guiding this thesis are outlined.

Chapter 2 covers the topic of "aural-visual impact of new wind parks", and studies and compares perception differences between the landscape with wind parks and the landscape without wind parks. The comparative analysis considering audio-visual interactive factors further investigates the negative impacts of wind parks on the public.

Chapter 3 studies "soundscape ambient wind parks". It presents the concept of soundscape and the relationship between soundscape characteristics and subjective responses related to wind parks.

Chapter 4 aims to evaluate the "validity of VR technology on the smartphone for the study of wind park soundscapes". It provides an overview of VR simulation in landscape planning with a specific focus on the relationship between realism, abstraction and individuals' responses to wind parks.

Chapter 5 summarizes the conclusions, contributions to knowledge and outlines areas for future research.

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# Chapter 2

# Audio-visual perception of new wind parks

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Research Paper

# Audio-visual perception of new wind parks

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ABSTRACT

Previous studies have reported negative impacts of wind parks on the public. These studies considered the noise levels or visual levels separately but not audio-visual interactive factors. This study investigated the audio-visual impact of a new wind park using virtual technology that combined audio and visual features of the environment. Participants were immersed through Google Cardboard in an actual landscape without wind parks (ante operam) and in the same landscape with wind parks (post operam). During the virtual exposure, the reactions of the participants to visual and noise impacts of the wind park were assessed using affective, cognitive, and subjective measures. Participants exhibited significant increases in aural annoyance post operam relative to ante operam. The same result was found in levels of visual annoyance. Aural annoyance and visual annoyance were significantly correlated. However, no direct effects of wind turbines on affective and cognitive measures were found, suggesting wind parks may not have obviously effects on people's objective disturbance. The perceived annoyance was associated with people's attitudes toward the wind parks, but not the sounds of the wind parks. These findings further our understanding of the objective and subjective effects of wind parks on human performance, and allow designers to make scientific decisions during the initial stage of a wind park planning.

## 1. Introduction

Wind parks, as environment friendly projects allowing the sustainable utilisation of wind energy, play an important role in securing and diversifying the supply of energy, reducing greenhouse gas emissions, and promoting sustainable economic growth (Molina-Ruiz, Martinez-Sanchez, Perez-Sirvent, Tudela-Serrano, & Lorenzo, 2011). Despite these positive potential contributions, they also pose potential environmental and particularly societal risks in sensitive regions, such as in tourist regions with scenic attractions (Otero et al., 2012; Sibille, Cloquell-Ballester, Cloquell-Ballester, & Darton, 2009). Wind park projects often encounter resistance from the public as the wind parks may not be well-suited for every landscape and may change both the visual and audible impression of a landscape (Ruotolo et al., 2012). The public resistance is also related to the awareness of negative consequences of wind parks on people and a local phenomenon known as "not in my backyard (NIMBY)" (Devine-Wright, 2005). This is a situation where one or more members of a community oppose a project too close to their homes due to fear of its anticipated negative consequences. Local residents may oppose a new wind park project, particularly if the wind parks are to be built close to them. The attitude of residents toward wind energy is one of the most important factors influencing people's preferences of wind parks (Pedersen, van den Berg, & Bakker, 2009). As a result, growing attention has been paid to social acceptance as a necessary aspect of the development of the renewable industry. Internationally, a number of examples have suggested that community participation in deployment facilitates social acceptance and support (Kontogianni, Tourkolias, Skourtos, & Damigos, 2014; Lam, Chan, Chan, Au, & Hui, 2009; Toke, 2005). In addition, case studies of existing wind park projects have stimulated analysis and evaluation of the aesthetic impact of wind park installation and potential impacts on people (Bishop & Miller, 2007).

A number of investigations have been conducted on the preference of wind parks, and have typically focused on either the acoustic or visual characteristics of wind parks (Bakker et al., 2012; Bishop & Stock, 2010; Devine-Wright, 2005; Kaldellis, Garakis, & Kapsali, 2012; Pedersen, van den Berg, Bakker, & Bouma, 2010). However, previous studies have reported negative impacts of wind parks on people, and may depend not on the noise or visual levels alone but instead on multi-perceptual factors (Hong & Jeon, 2014; Maffei et al., 2013; Ruotolo et al., 2012). A number of behavioural and neuropsychological studies have showed a reciprocal relationship between visual information and auditory judgments (Benfield, Bell, Troup, & Soderstrom, 2010; Iachini et al., 2012). Most previous studies used a unimodal approach with

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photographs or pre-recorded sounds presented separately (Molnarova et al., 2012; Otero et al., 2012) but fewer studies applied an audio-visual approach that combined this information (Manchado et al., 2013; Rodrigues, Montanes, & Fueyo, 2010). Limited research has assessed the visual impact of an existing or future wind park infrastructure by 3-dimensional graphic reconstruction on the 1:1 scale (Ruotolo et al., 2013). A better method that captures both auditory and visual features of environment is needed for effective assessment of audio-visual impact (Bishop & Rohrmann, 2003). To achieve this goal, virtual reality (VR) technology provides an excellent opportunity for use in environmental impact studies (Iachini et al., 2012; Maffei et al., 2013; Ruotolo et al., 2013). VR allows the presentation of multisensory environment with embedded aural and visual components and enables an experience very similar to real life experience (Jankowski & Decker, 2013). By letting individuals experience the environment of a wind park and exploring their perceptions, VR technology can provide unique evidence for optimization of wind turbine numbers, types and positions (Wan, Wang, Yang, Gu, & Zhang, 2012).

The impacts of wind parks on mental health have been widely studied. The visual disturbance and noises caused by wind parks have been associated with chronic fatigue. Exposure to a natural environment is linked to psychophysiological restoration, including improvement of affective and cognitive functions (Brambilla, Gallo, Asdrubali, & D'Alessandro, 2013; Bratman, Daily, Levy, & Gross, 2015; Hartig & Staats, 2006). Humans often feel restored, or respond positively to exposure to nature, with both cognitive and affective responses. Cognitive refers to rational effects, "from the head", and the affective parameter refers to more emotional responses, "from the heart". Wind parks may limit the degree of this restoration that humans feel in response to a landscape (Pedersen & Larsman, 2008). There have been some studies of the relationships between psychoacoustic level and cognitive functioning (Iachini et al., 2012; Ruotolo et al., 2012; Ruotolo et al., 2013) and a psychophysiological study on the visual impact of wind parks (Maehr, Watts, Hanratty, & Talmi, 2015). (Manyoky, Wissen Hayek, Pieren, Heutschi, & Grêt-Regamey, 2016) evaluated the effect of wind parks on subjective factors using audio-visual simulation, but did not investigate the affective and cognitive factors. There has been no qualitative research on the psychophysiological effect of wind parks infrastructure with embedded audio-visual environment features, and a more comprehensive assessment of wind park projects should include affective and cognitive measures (Knopper & Ollson, 2011; Manchado et al., 2013).

This study, therefore, aims to assess the impacts of wind parks on individuals' affective and cognitive functions, to evaluate individuals' responses to wind parks, and to determine whether their subjective responses were affected by non-visual acoustic factors. Three hypotheses were tested: (1) compared to the landscape without a wind park, a landscape with a new wind park influences individuals' affective and cognitive functions; (2) wind parks increase both visual annoyance and audio annoyance; (3) visual and audio annoyance are correlated and the perceived annoyance is associated with individuals' attitude toward the wind parks. Using virtual reality technology, scenarios were created to evaluate a landscape (without wind parks) and the same landscape with the projected wind parks. In each scenario, participants rated the noise and visual annoyance, and were subjected to cognitive functioning tested including short-term verbal memory and executive control.

## 2. Methodology

### 2.1. Auditory and visual materials

The present study used a large rural area located in Dummerstorf (northern Germany) (Fig. 1). This area is the planned location for a new wind park to help meet the German electricity supply needs. Many local residents use this area as an outdoor recreation site, and comprehensive assessment of impact is required.

In the data preparation stage, audio-visual recordings were made in the field of the projected wind park in Dummerstorf with clear weather from 11:00 am to 3:00 pm, considering that outdoor activities are most frequent during this period. Binaural recordings were made using a dummy head with a height of 1.6 m and a recorder (DAT 208Ax, Sony). Observed images were also taken using a digital camera (EOS 350 D, Canon) at a height of 1.6 m. The position with distance to wind park greater than 1000 m was suggested to have little impact from wind park (Jallouli & Moreau, 2009). Thus, three representative positions from the projected wind park were selected for recording (Maffei et al., 2013): 150 m to the closest wind turbine (DI), 250 m to the closest wind turbine (DII), and 500 m to the closest wind turbine (DIII) (Fig. 1). Additionally, a multi-source recording was generated (two wind turbines from different directions). At each position, around 20 visual images were taken from different angles and 360° panoramic views were constructed.

In order to simulate the post operam scenarios that reproduce the area in Dummerstorf with the addition of the projected wind park, corresponding aural materials were needed. The related binaural recordings were separately collected at three distances from the closest wind turbine in an existing wind park site located in Kirchmulsow (Germany). This site was selected due to its similarities to the projected wind park at Dummerstorf. Both sites are located in flat rural areas with gravel roads that are surrounded by fields. The audio signal recordings of the existing background noise were utilized as the post operam auditory stimuli. A total of six sounds were selected from real survey observation points. Dummy head recording was used to generate binaural recordings to create a realistic 3D sound. All the sounds were recorded in .wav format with a sampling frequency of 44,100 Hz. The observation point, and characteristics of the sounds used in the test are listed in Table 1. The analysis of A-weighted-sound-pressure-level (SPL) and four psychoacoustic variables of sharpness (S), fluctuation strength (F), loudness (N) and roughness (R), which were commonly suggested metrics in the evaluation of an aural environment (Maffei et al., 2013; Zwicker & Fastl, 1999), was performed using the Artemis (Head Acoustics) software.

In this study, a commonly used VR tool was employed, unity 3d, which supports the smartphone platform and allows the use of scripting languages with low cost and easy access distribution. The use of VR technology tools allows presenting the wind park project in a way that is illustrative, interactive, and intensive. In contrast to pictures and video recordings, it has been demonstrated in number of previous studies that VR can be reliably used to assess a multi-sensory environment and allow the participation to interact with simulated world (Iachini et al., 2012; Portman, Natapov, & Fisher-Gewirtzman, 2015; Ruotolo et al., 2013). Moreover, the integration of dynamic vision and sound provides a realistic sense of presence in the environment for the participant, and thus provoke responses and behaviours similar to those that would occur in the real environment. In Iachini's research, different real-world metros were simulated using VR technology to assess acoustic comfort. In Ruotolo's research, VR technology was used to investigate the potential negative effects of a new motor way.

The visual stimuli of the wind park was thus created by unity 3D with consideration of the visualization of the build environment and the ground of the area. The area and the wind turbines (height: 103 m, diameter of rotor: 105 m) were modelled and photo-realistic texture was applied in unity 3D using the 3ds Max modelling software. Both the auditory and visual components of the scenarios were uploaded to make the virtual environment as realistic as possible. The duration and loudness of sounds were normalized before being imported into unity 3D. Finally, ante operam and post operam scenarios were created for three positions that varied in their distance to the nearest wind turbine (DI, DII, and DIII):

- ante operam (an actual landscape without the projected wind park),
- post operam (the same landscape with the projected wind park).

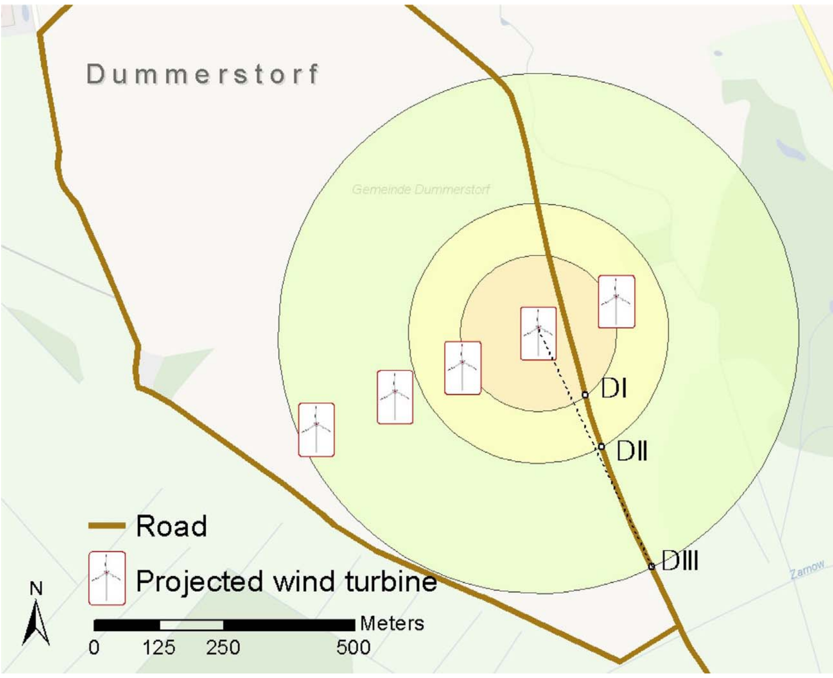



**Fig. 1.** The entire simulated area is illustrated from a survey perspective. DI, DII and DIII indicate the observation points from where participants experienced the virtual scenarios. Three buffer zones were established at 150 m, 250 m, and 500 m from the closest projected wind turbines, respectively. Data acknowledgement: RERP Rostock, wind energy planning agency and the GDI MV, digital topographic cartographic information system.

**Table 1**
Observation point, acoustic, and psychoacoustic characteristics of the six sounds used in the test (mean values at the six observation points). SPL: A-weighted sound pressure level; N: loudness; S: sharpness; R: roughness; F: fluctuating strength.

| Observation point | Scenario | SPL/dBA | N/SoneGF | S/Acum | F/Vacil | R/Asper |
|---|---|---|---|---|---|---|
| DI | 150mAnte | 72.8 | 6.2 | 2.2 | 0.0 | 0.7 |
| | 150mPost | 87.8 | 23.0 | 1.4 | 0.1 | 2.0 |
| DII | 250mAnte | 69.5 | 9.7 | 1.1 | 0.0 | 1.0 |
| | 250mPost | 92.0 | 27.3 | 1.2 | 0.1 | 2.3 |
| DIII | 500mAnte | 65.7 | 5.1 | 2.9 | 0.0 | 0.7 |
| | 500mPost | 87.2 | 21.0 | 1.0 | 0.1 | 1.8 |

A total of 6 scenarios were simulated and merged into mobile devices. Selected views of the six scenarios are illustrated in Fig. 2.

### 2.2. Participants

To achieve a power of at least 0.80 for the within subject ANOVA, G*Power 3 suggested a total of 18 participants (Erdfelder, Faul, & Buchner, 1996). In the study of perception on audio-visual stimuli in a controlled laboratory setting, the subject sample size of 20 is often used and found to be reasonable (Joynt & Kang, 2010; Ren & Kang, 2015a, 2015b). To minimize the effect of variation among subjects, university students were used as subjects, based on which further experiments could be made using other subject groups. Therefore, a total of 20 university students from University Rostock (Mean age: 26.7 years, standard deviation (SD): 4.1) participated in this study. Based on the selection criteria of previous studies (Lee, Hong, & Jeon, 2014; Ruotolo et al., 2012; Weinstein, 1978), young people with normal hearing and regular or corrected to normal vision were selected as study subjects.

### 2.3. Measures

Affective responding (skin conductance, heart rate, and other physiological indicators of stress) can be influenced by picture and video stimulus of natural scenery (Gladwell et al., 2012; Laumann, Gärling, & Stormark, 2003; Ulrich et al., 1991). However, few studies have examined the impacts of wind parks project on affective responses. Positive affect and negative affect are main distinguishing features of the level of emotional distress of people (Denollet & De Vries, 2006). In this study, the Positive and Negative Affect Schedule (PANAS) was used during the test period to measure the degree of the mood of participants (Watson, Clark, & Tellegen, 1988). This test is divided into two scales (positive and negative), each consisting of ten items of emotional states (e.g., excited, upset, or nervous). Participants were asked to select their response on a 5-point Likert scale. (1 = "Strongly disagree", 2 = "disagree", 3 = "neutral", 4 = "agree" and 5 = "Strongly agree"). The scaling approach has been used previously for measurement of PANAS (Bratman, Hamilton, & Daily, 2012; Watson et al., 1988; Zelenski & Nisbet, 2014).

Numerous studies have suggested that wind parks can negatively affect on people's cognitive functions and thus influence the daily life. People may not feel annoyed by wind parks, but objective measures may show cognitive effects, and vice versa. Subjective measures (aural and visual annoyance) can provide essential information, but objective measures are necessary to quantitatively describe the impact of wind parks on people. For cognitive assessment, the backward digit span task (BDS) was selected, as it is the primary measure of working memory. To assess the impact of noise on cognitive measures, participants had to perform the BDS task for each virtual immersion. This task is used to measure domain-specific storage capacity, as phonological information is stored in the short-term memory (Bratman et al., 2015). For this task, numerical sequences were read aloud automatically by a computer at a rate of one per second. The sequences were then repeated aloud by each individual in a reverse order. Sequences were three to nine digits in length, with two trials of each digit length (Berman, Jonides, & Kaplan, 2008). For the first two trials, individuals were given three digits to remember (e.g., for length three: "3, 6, 1" and "8, 2, 7"). If an individual correctly answered at least one of the two trials, then the length of the digit span was increased by one, and the individual recalled the new two trials in the reverse order. This continued until the individual was unable to repeat both trials at a particular length, or he/she completed

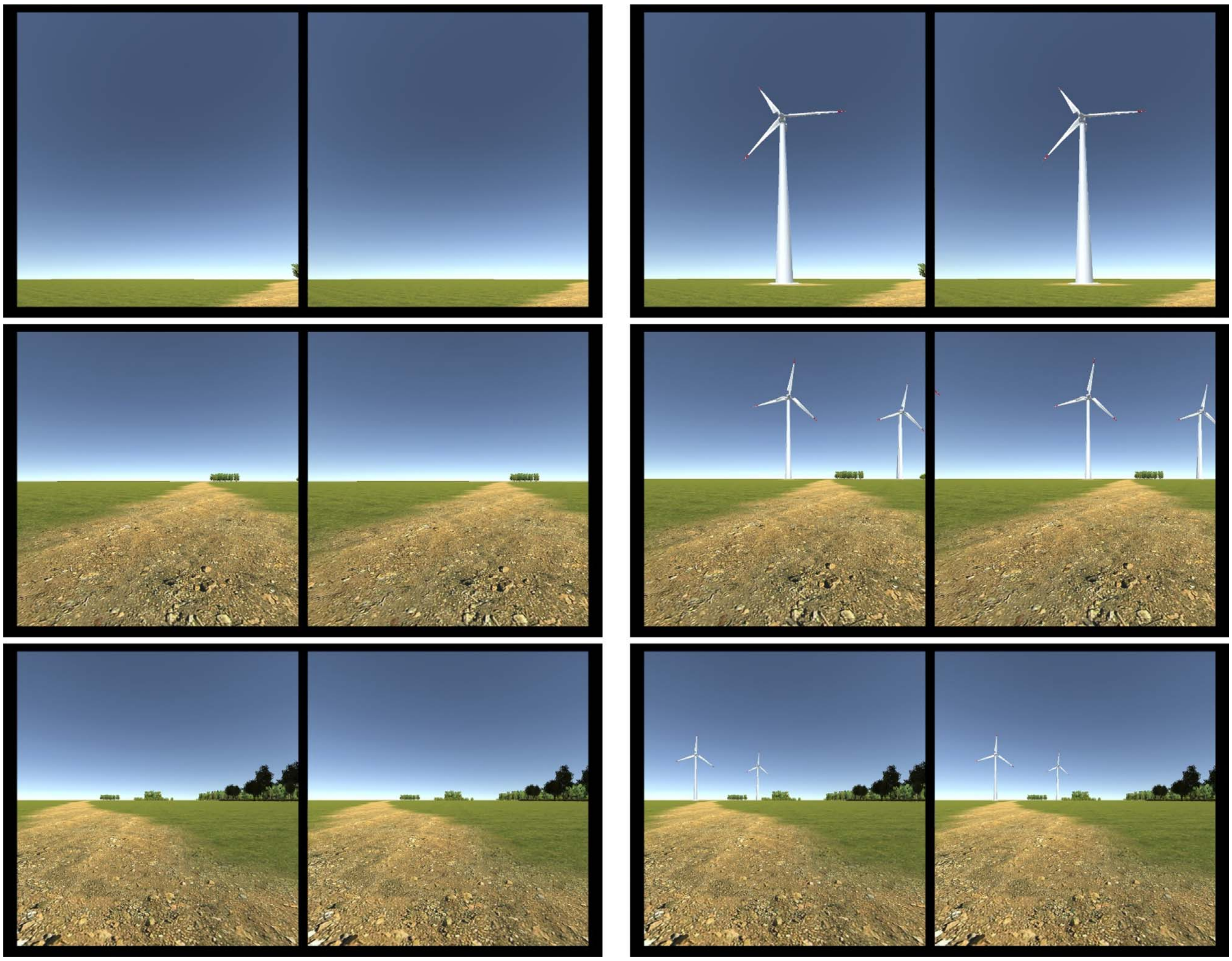


**Fig. 2.** Selected views as seen by participants through google cardboard from each observation point DI, DII, and DIII in the ante and the post operam conditions according to the fields of view indicated. DI (top row); DII (middle row); and DIII (bottom row). Ante Operam (left column); Post Operam (right column).

the maximum length of nine digits. In each successful set, an individual gets one point and the total number of points represents the score of each individual on BDS task.

To evaluate the effect of the audio-visual scenarios on participants, a questionnaire was administered. The questionnaire used an 11-point scale (0–10), offering high reliability and ease of acquiring statistical information. The questionnaire included a question about the visual features "How much did the visual aspects of the scenario annoy you?" and a question about the audio features "How much did the auditory aspects of the scenario annoy you?"

Additionally, to investigate the effects of non-visual acoustic factors on the subjective responses, the preferences of participants toward a new wind turbine (A1), toward integration of a wind park (A2), toward sound of wind turbines (A3) and toward more wind turbines (A4) were assessed using the same 11-point scale.

### 2.4. Procedure

Participants sat in a quiet room (< 40 dB) wearing a Google Cardboard headset with an embedded mobile device presented via the open source software unity 3D (Fig. 3). Unity 3D allows head-tracking, which was realized with the aid of a unity script when participants were wearing the headset. This used a mobile device equipped with a gyroscope to detect exactly where the participants were looking, with an integrated three dimensional audio, in which the sounds and scene view move in an immersive 360° in response to head movements.

Acoustic stimuli were delivered through in-ear headphones plugged into the mobile device, which were chosen because they are light weight, ubiquitous, have a frequency range of 20–20 kHz, and are easily used in augmented reality applications (Martin, Jin, & van Schaik, 2009). The test sound level and the on-site recorded one were closely identified with each other as determined before the start of testing. All testing procedures were carried out between 10:00 and 14:00 h in a quiet room, to avoid any effect of circadian rhythm.

The testing phase consisted of six scenarios (3-distance [DI, DII and DIII]*2-condition [ante operam and post operam]) (Fig. 1), each lasting approximately 32 s. Immediately after each virtual immersion, participants had to perform the PANAS, BDS, and subjective tasks (Fig. 4). Each participant experienced six virtual scenarios and used a questionnaire form to mark his or her answers.

### 2.5. Data analysis

The present study used SPSS version 22 to conduct the following analysis. For the main analyses, 3*2 factorial analyses of variances (ANOVA) on each dependent measure were performed, with distance (DI, DII and DIII) and condition (ante vs. post operam) considered separately as the within-subject factors. In all analyses, the Bonferroni correction was applied to account for multiple testing and set significant differences at an error probability $\alpha$ ($p = 0.05$). Normal distribution and variance homogeneity were tested in advance. Additionally, partial eta squared-values ($\eta_p^2$) were determined to measure the effect sizes. In order to assess whether there was less difference with and

**Fig. 3.** Wind park 3D-environment created within Unity, sample viewed by individuals during testing.

without wind turbines if the wind turbines were located farther away compared to the difference when the wind turbines were located closer, the effect of distance on the perception of wind turbines was examined. Furthermore, in order to examine the impact of the attitudinal factors on participants' evaluation, the interaction between their attitudes to wind power and their evaluation results was examined.

## 3. Results and discussion

### 3.1. Affective impact and cognitive impact

Evoked affective responses to the simulated landscape with different condition (ante vs. post operam) and distance (DI, DII and DIII) were compared as shown in Fig. 5. The ANOVA on affective responses were performed for distance and each condition. As shown in Fig. 5, the ante and post operam scenarios did not influence the affective values for individuals. Additionally, over the stimuli period, there was no distance effect found for the affective measures. The statistics for each of these findings are reported below.

The ANOVA on positive affect (PANAS) showed no main effect of condition, $F(1, 19) = 0.486$, $p = 0.487$, $\eta_p^2 = 0.004$, or distance, $F(2, 38) = 0.132$, $p = 0.876$, $\eta^2{}_p = 0.002$. The positive impact at baseline is shown in Fig. 5A. There was no significant change in the positive affective scores relative to the baseline, but positive values were decreased in the post operam stimuli.

The ANOVA on negative affect (PANAS) showed no main effect of condition, $F(1, 19) = 0.446$, $p = 0.506$, $\eta_p^2 = 0.004$, or distance, $F(2, 38) = 0.012$, $p = 0.988$, $\eta^2{}_p = 0.000$. The negative affect at baseline is shown in Fig. 5B. There was no significant change in the negative affective scores relative to the baseline, but an increase of negative values was found in the post operam stimuli compared to the post operam stimuli.

The responses to the task of BDS for the different scenarios are shown in Fig. 6. As can be seen in Fig. 6, ANOVA of the BDS test did not show significant effects of condition, $F(1, 19) = 1.553$, $p = 0.215$, $\eta_p^2 = 0.013$ and no effect of distance, $F(2, 38) = 0.119$, $p = 0.887$. Thus, no significant differences were found for affective impacts and BDS scores between the conditions or distances with wind turbines.

Compared to the scenarios without wind parks, the scenarios with wind parks showed a distinct trend for negative and positive values, but not at an acceptable significance level. There were also no significant differences found in cognitive performance between the ante and post operam scenarios. Thus, the results did not support the first hypothesis that new wind parks could affect affective and cognitive performances.

These findings found no significant influences of wind parks on affective and cognitive impact. This is consistent with other work that suggests that there are no direct significant effects of wind turbines on psychological stress (Bakker et al., 2012). A review from (McCunney

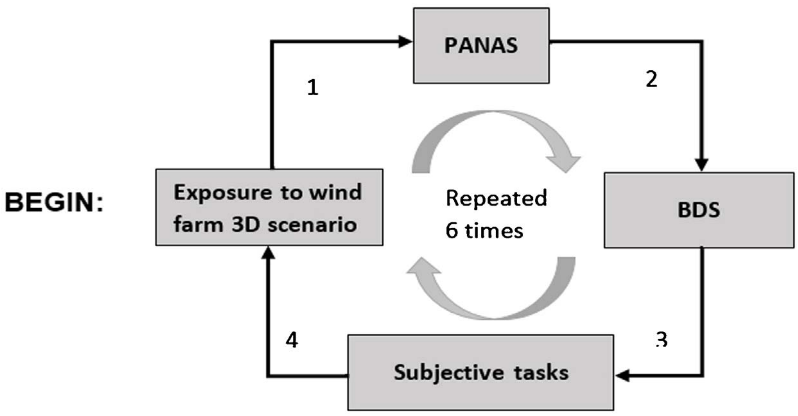
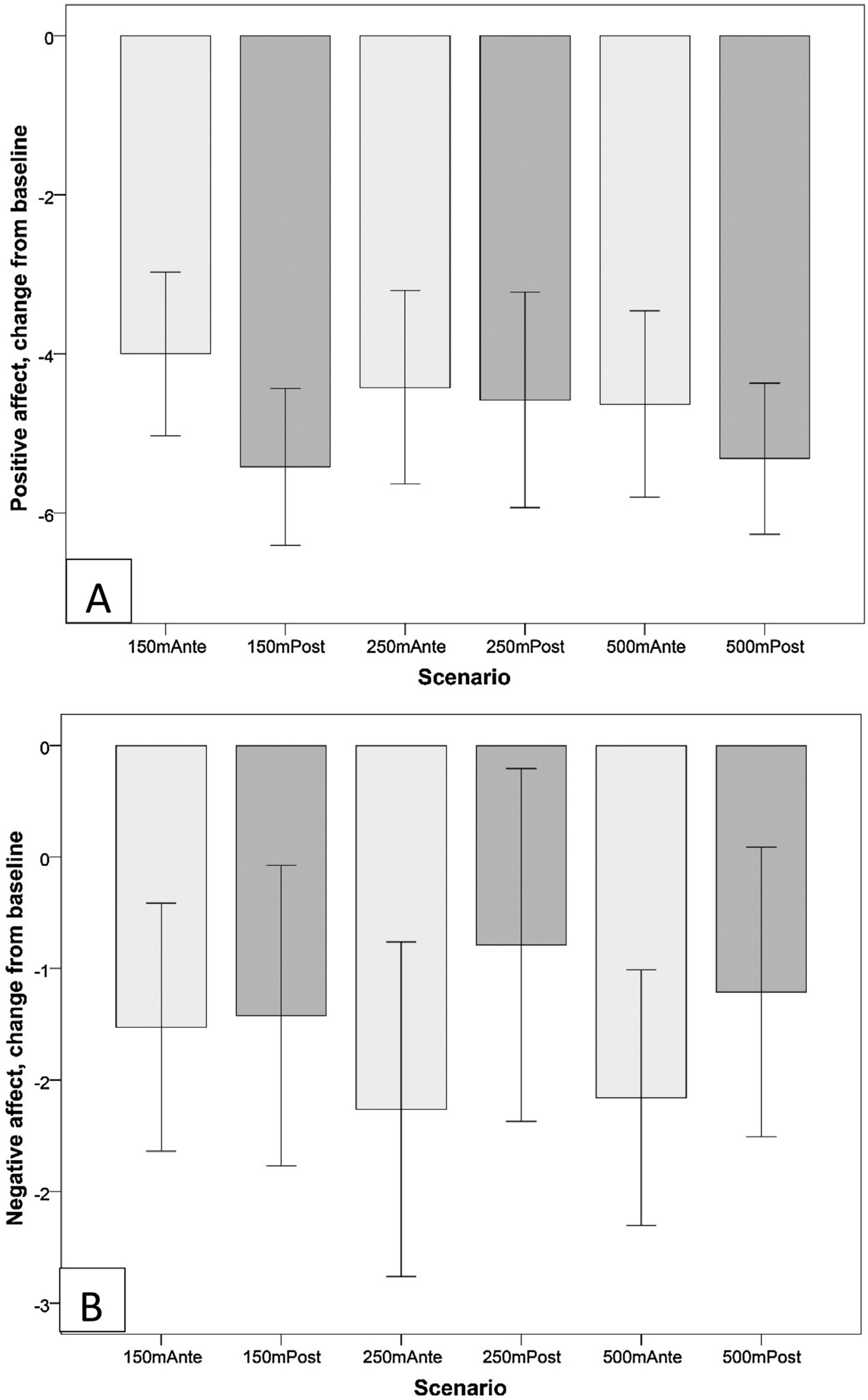



**Fig. 4.** Schematics of experimental setup in the test period (PANAS, positive and negative affect schedule; BDS, backward digit span.).




*** = p < 0.001

**Fig. 5.** Affective impact of test scenarios. Different scores are used to compare performance from Ante to Post wind turbines (a negative value indicates a decrease after immersion; a positive values indicate an increase). Scores in the test scenarios are indicated for each panel on the two affective measures: (A) positive affect, (B) negative affect. Error bars depict standard error (SE) values.

et al., 2014) also suggested that the sound of wind turbines was insufficient to cause stress or other adverse health effects in humans. In addition, studies demonstrated that auditory information can improve related visual displays and vice versa (Carles, Bernáldez, & Lucio, 1992; Southworth, 1969). If one experiences visual displays without sounds context, it can be perceived as more annoying. Further study with audio-only, visual only, and audio-visual only conditions is required to investigate whether the representation of an audio-visual wind park environment may alter the impact on psychological distress.

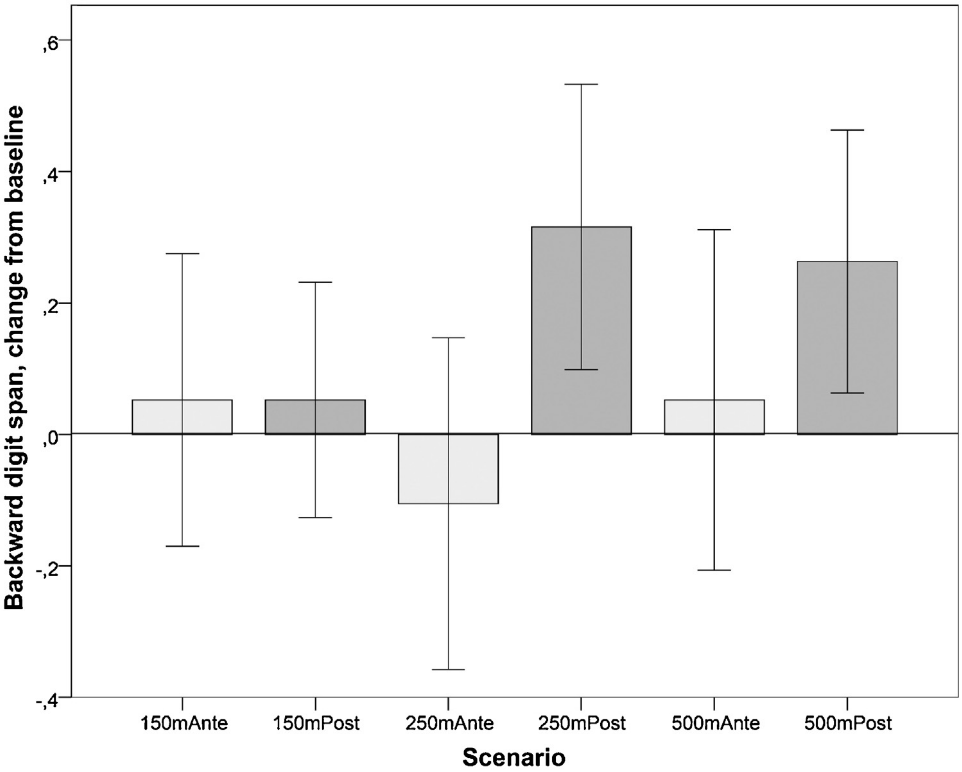



**Fig. 6.** Cognitive impact of test scenarios. Different scores are used to compare performance from before the test to performance afterward (positive values indicate an increase after the test). Scores on the cognitive measure (BDS) are indicated in the test scenarios for each panel. Error bars depict standard error (SE) values.

### *3.2. Visual annoyance and aural annoyance*

ANOVA was used to compare the condition (ante vs. post operam) and distance (DI, DII and DIII) on ratings of visual and aural annoyance (see Fig. 7). As shown in Fig. 7, participants within the post operam scenarios felt more annoyance than people experiencing the ante operam scenarios. Post operam scenarios led to greater increases in aural and visual annoyance. No effects were evident for distance factors. Similarly, the subjective tasks did not show a significant effect between condition and distance. The statistics for each of these findings are presented in detail below.

For visual annoyance, the ANOVA results yielded a significant main effect of condition, $F(1, 19) = 45.202$, $p < 0.001$, $\eta_p^2 = 0.284$. No interaction between distance factor was found, $F(2, 38) = 0.358$, $p = 0.7$, ${\eta^2}_p = 0.006$. Fig. 7A shows a higher annoyance in the DI and DIII positions in the operam scenarios, indicating that participants rated scenarios as more visually annoying when they are directly under wind turbines and close to them, at distances of 150 m and 500 m. Finally, there were no significant difference between annoyance ratings across the three scenarios for the ante operam condition (see Fig. 7A).

For aural annoyance, the ANOVA results revealed a significant main effect of condition, $F(1, 19) = 27.023$, $p < 0.001$, $\eta_p^2 = 0.186$. Aural annoyance was higher for post operam scenarios than in ante operam scenarios (see Fig. 7B). This outcome reveals that the introduction of wind parks into the landscape can have negative impact on participants' evaluation of the soundscape. No interaction between the distance factor was found, $F(2, 38) = 0.007$, $p = 0.993$. Fig. 7B shows slightly higher annoyance in the DI and DII positions in the post operam scenarios, suggesting participants rated those scenarios as more visually annoying when they were closer to the noise source than the DIII position. Finally, there was no significant difference between the annoyance ratings for the three scenarios under the ante operam condition (Fig. 7B).

The participants' subjective responses provide evidence that landscapes with wind parks have negative influences compared to landscapes lacking wind parks. These negative influences were mainly subjective, as the landscape with wind parks increased both visual and aural annoyance, in contrast to affective and cognitive impacts. People felt annoyed by wind parks, but objective measures revealed no cognitive effects that support the first hypothesis. This result indicated that relatively short duration effects on wind parks affective and cognitive performances are independent of perceived annoyance, which is probably due to the fact that human performance is mainly influenced by speech noise in background (Szalma & Hancock, 2011).

For the scenario located closest to the wind parks, there were higher visual and aural annoyances in both cases. However, no significant differences were found in the present study between the participants' evaluation for the three test distances across both ante operam and post operam scenarios, although distance may influence the perceived impact (Maffei et al., 2013).

### *3.3. Perceived annoyance and attitude toward wind parks*

The correlations between the preference scores for the four attitudinal factors and the subject responses under the six conditions were calculated. The results are listed in Table 2. Significant differences were found between preference groups for the subjective responses obtained under the six conditions (see below).

For aural annoyance, the results showed that participants were less aurally annoyed if they were more accepting of the integration of a new wind turbine. A significant negative correlation between preference for integration of wind park and aural annoyance was found (Spearman's correlation coefficient $r = -0.373$, $p < 0.01$). However, attitudes toward the sound of wind turbines and attitudes toward more wind turbines were not significantly correlated with aural annoyance.

For visual annoyance, the relationship with preference of a new

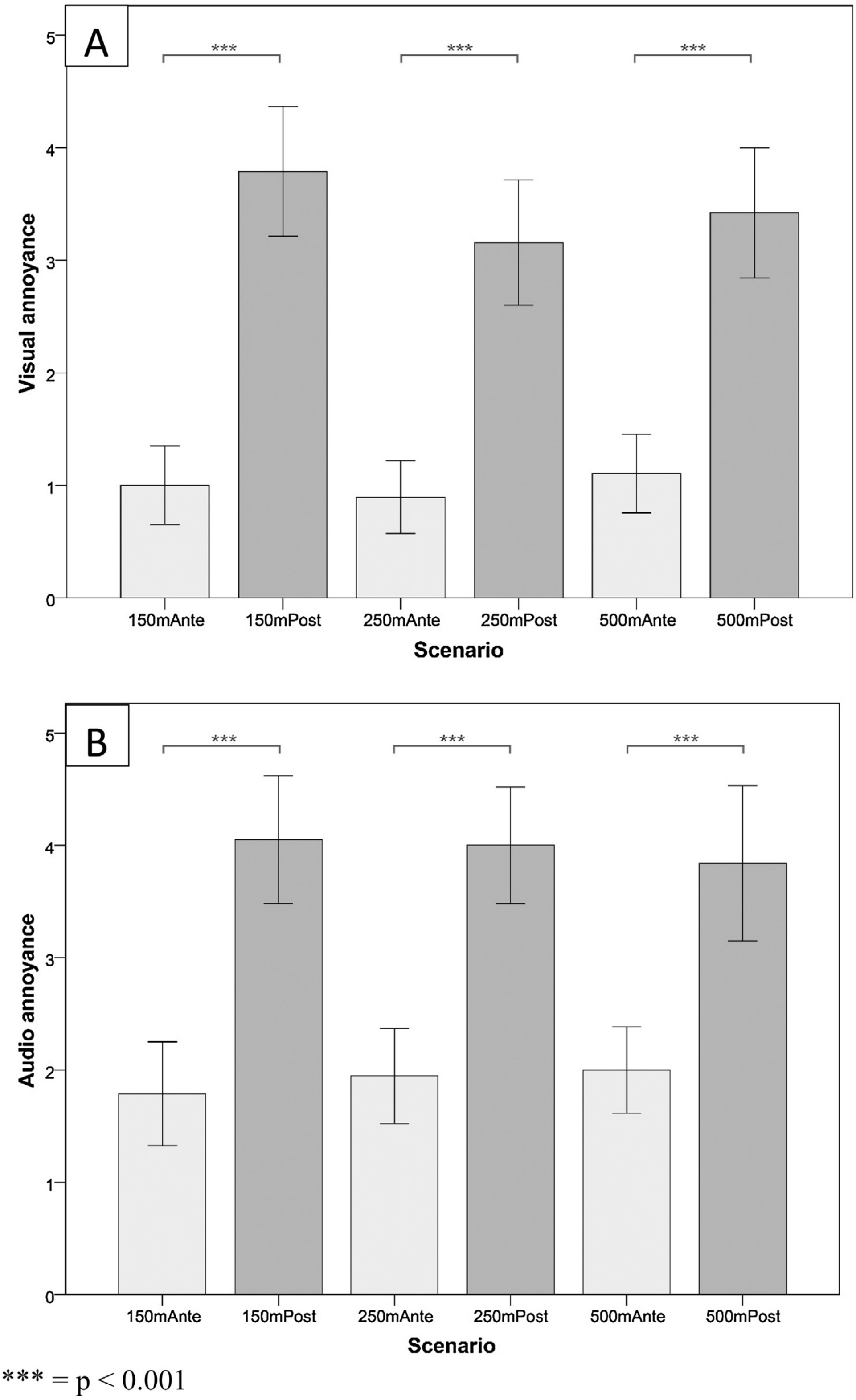



**Fig. 7.** Subjective ratings of ante/post operam and three distance scenarios. Different scores are used to compare performance from Ante to Post wind turbines (a negative value indicate a decrease after immersion; positive values indicate an increase). Scores in the test scenarios are indicated for each panel on the two subjective measures: (A) visual annoyance, (B) audio annoyance. Error bars depict standard error (SE) values.

wind turbine was negatively correlated and statistically significant ($r = -0.299$, $p < 0.01$). A negative correlation between preference for the integration of a wind park and visual annoyance was also found ($r = -0.425$, $p < 0.01$). However, the individuals' attitude toward the sound of wind turbines and attitude toward more wind turbines showed no significant correlation with visual annoyance.

Previous studies have reported that noise annoyance and visual annoyance are associated with negative attitude toward a wind park (Molnarova et al., 2012; Pedersen et al., 2009). However, the correlation between attitude toward the sound of wind turbines and perceived

**Table 2**
Correlation coefficients between attitude preference and subjective annoyance.

| | A1 | A2 | A3 | A4 | VA | AA |
|---|---|---|---|---|---|---|
| A1 | 1 | | | | | |
| A2 | 0.527** | 1 | | | | |
| A3 | 0.305** | 0.175 | 1 | | | |
| A4 | 0.687** | 0.326** | 0.374** | 1 | | |
| VA | −0.299** | −0.425** | −0.094 | −0.127 | 1 | |
| AA | −0.022 | −0.373** | −0.081 | 0.115 | 0.709** | 1 |

A1, attitude toward a new wind turbine; A2, attitude toward integration of wind park; A3, attitude toward sound of wind turbines; A4, attitude toward more wind turbines; VA, visual annoyance; AA, aural annoyance.
** $p < 0.01$.

**Table 3**
Correlation of scenarios' acoustic metrics with subjective annoyance.

| Acoustic metrics | Subjective annoyance | |
|---|---|---|
| | Visual annoyance | Aural annoyance |
| Sound pressure level (dBA) | 0.470** | 0.371** |
| Loudness (SoneGF) | 0.465** | 0.380** |
| Sharpness (Acum) | −0.231* | −0.177 |
| Fluctuation strength (Vacil) | 0.490** | 0.379** |
| Roughness (Asper) | 0.465** | 0.380** |

* $p < 0.05$.
** $p < 0.01$.

audio-visual annoyance was not examined. The correlation between the general preference toward a new wind park and perceived annoyance was significantly negative in this study, but no significant correlation was found between perceived annoyance and attitude toward the sound of wind turbines. This result is probably due to the fact that individuals normally have a negative opinion toward the sound of wind turbines and the perceived annoyance was often reduced when the sound of wind turbines was masked by natural sounds in the background (Bolin, Nilsson, & Khan, 2010; Ren & Kang, 2015a, 2015b). Overall, the higher the negative attitude toward wind park, the higher the annoyance. This result correlates favorably with the previous findings and further supports the idea that the attitude of the public toward a wind park is a determining factor for perceived annoyance about wind parks. Thus, the prior participation of local residents in the planning of wind parks may improve attitudes and facilitate the introduction of wind parks.

Furthermore, there was a significant correlation between visual annoyance and aural annoyance ($r = 0.709$, $p < 0.01$), and the higher the visual annoyance, the higher the aural annoyance. The strong correlation between aural and visual annoyance confirms the fact that auditory annoyance is matched with visual annoyance in the tasks. This finding is consistent with previous studies that aural information and visual information are interpreted in a closely related manner, thus confirming the concept that humans respond to their environments holistically (Liu, Kang, Behm, & Luo, 2014; Ruotolo et al., 2013).

The analysis showed that individuals perceived noise annoyance more strongly than visual annoyance (averaged annoyance score: 3.8 vs.4.05, 3.15 vs. 4, and 3.4 vs. 3.85 at different distances DI, DII, and DIII, respectively in post operam scenarios). This suggests that noise is one of the most dominant interfering factors when subjects are relatively close to wind parks.

Further correlations between perceived annoyance and acoustical characteristics are shown in Table 3. Overall, visual and aural annoyance were correlated with the acoustical characteristics. Other than the value of sharpness which showed a reverse trend for both perceived annoyance, the higher the acoustical level of SPL, loudness, fluctuation strength, and roughness were, the higher the annoyance rating. This result confirms the importance of sound information and provides further evidence that the use of photographs alone is insufficient to study the impacts of wind parks.

## 4. Conclusions

To summarize, in this study noise and visual intrusion from wind parks did not cause significant influences on affective nor cognitive performances even if the individuals subjectively experienced more annoyance when wind parks appear in the landscape. Hence, at least when considering relatively short exposures, it would seem that the perceived annoyance associated with performing cognitive tasks under these conditions might not substantially affect physiological stress as measured by affective and cognitive measures.

In addition, the survey results suggest that the introduction of a wind park would have a significant negative influence, likely due to the increase in both aural and visual annoyance. The findings support the model that exposure to wind parks can contribute to annoyance and this annoyance is not solely caused by wind turbine noise but also by visual impacts.

Further results indicated that aural annoyance tended to correlate with visual annoyance. This finding suggests that noise is a main interfering factor that affects the preference of wind parks and confirms the importance of considering sound information in impact studies of wind parks (Qu & Kang, 2017). Additionally, in this study the perceived annoyance was associated with attitude of public toward wind parks, but not correlated with their attitude toward sounds of wind parks.

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# Chapter 3

# Assessment of soundscape ambient wind parks

This chapter is based on the manuscript
"**Tianhong Yu**, Holger Behm, Ralf Bill, Jian Kang, Assessment of soundscape ambient wind parks, Landscape and Urban Planning, under review."

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**Abstract**: The potential conflicts between wind parks and the public have been enormously enhanced with increasing development of wind power. Noise annoyance has played a vital role in the reaction of the people concerning to wind parks. This study uses an audio-visual preference survey to systematically investigate the effects of background soundscapes and non-aural factors on annoyance towards wind parks. Visual and acoustic data were captured from 7 German rural wind park sites. Laboratory experiments were then carried out with 40 participants to investigate the perception of the wind park project in rural areas. The tests consisted of three parts: 1) visual-only condition, 2) audio-only condition, and 3) combined audio-visual condition. Participants were immersed through Google cardboard in laboratories using virtual reality technology to evaluate the properties of sound and visual environment. It was found that annoyance towards wind parks strongly correlated with sound level ambient wind parks. However, the visual information did not demonstrate substantial effects on the preference towards wind parks. Further results show that soundscape ambient wind parks associated with factors including "sound quality", "relaxation" and "diversity". Among them, "sound quality" and "relaxation" were significantly correlated with sound level and the perceived annoyance. Moreover, the reconstruction of a realistic audio-visual environment on the smartphone allows public participation and the realism of the simulation strongly influenced by the congruency of visual and sound content.

**Keywords**: Soundscape; audio-visual impact assessment; virtual reality; Wind parks

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## 3.1 Introduction

The development of wind power is a global trend for a better environmental friendly energy supply compared to sources such as nuclear and coal. There is universal acceptance for the development of wind power. However, the “not in my backyard” syndrome (NIMBYism) often exists with respect to wind parks (Devine-Wright, 2005), which there are oppositions between residents for the development of wind power on the local level when wind park projects are planned directly nearby. The risk of acceptance of wind parks in the landscape has been enormously enhanced with increasing development of wind power. The potential conflicts to wind parks can be related to annoyance for the public, and it was suggested that their effects on human health should be assessed (Knopper and Ollson, 2011; Wang and Wang, 2015).

A dose-response relationship between wind parks and health-related effects such as annoyance, sleep disturbance, and possibly psychological distress was found (Gibbons, 2015; Kontogianni et al., 2014; Schmidt and Klokker, 2014). Various investigations have further explored the possible factors that influence the potential conflicts of wind parks and indicated the main factors affecting the annoyance, including visual intruders (Maehr et al., 2015; Palmer, 2015), the noise of wind turbines (Kontogianni et al., 2014; Taylor et al., 2013), attitudes towards wind parks (Yu et al., 2017) and economic benefits (Christidis et al., 2017). To examine if natural sounds can reduce annoyance towards wind turbine noise, Bolin conducted the listening test, and the results indicated that the masking effect could happen if the level of background sounds is higher than the wind park noise only (Bolin et al., 2012). Visual factors on the influence towards noise annoyance of wind parks have been examined, and the results found that negative visual attitude mainly impacts the noise annoyance (Pedersen and Larsman, 2008). Besides, the number of the wind turbines being able to see is also found as an influential situational factor affecting annoyance (Janssen et al., 2011).

The concept of the soundscape, which refers to “acoustic environment as perceived or experienced and/or understood by a person or people, in context” (ISO12913-1, 2014), was suggested by numerous researchers as a critical factor for understanding the perception of a particular acoustic environment (Brown et al., 2011; Kang et al., 2016). The soundscape characteristics including sound level were the prominent aspect of the annoyance evaluation (Szychowska et al., 2018). Also, soundscape can dominate the preference degree to the environment due to its component and places with environmental identity (Carles et al., 1992, 1999). Soundscape in the rural area is a complex system, perceptual measure using multidimensional indices (semantic differential technique) is a crucial factor to characterize the soundscape and verify its environmental identity. Previous researchers have demonstrated the need for the categorization of the soundscape in different levels (Guastavino, 2007; Kang and Zhang, 2010; Torija et al., 2013; Viollon et al., 2002). Researchers have used laboratory protocols to examine the influence of the sound to outdoor settings quality and indicated the enhancing effect of nature-related sounds on residential setting quality (Anderson et al., 1983). Studies on traffic noise annoyance have widely been investigated, for instance, the influence of visual aspect of barriers on railway noise annoyance has been examined (Maffei et al., 2013). However, the impact of ambient sound characteristics on annoyance to wind turbines which are placed mostly in rural or mildly built-up areas was so far not clear (Janssen et al., 2011). Besides, the residents near to wind turbines may spend a higher proportion of their time outdoors, thus considering the influence of the future ambient soundscape on wind park annoyance could be a supplement for the annoyance study on wind parks. In the context of wind parks, a holistic approach to investigate the soundscape around wind parks and their effects should be conducted to improve quality of life in rural areas.

Landscape environment is rarely perceived in isolated but in a multisensory way. Previous studies have confirmed the importance of the interaction between aural and visual information. The vision and audition are commonly accepted as the significant modalities to perceive the environment (Hong and Jeon, 2014). Previous studies tested virtual reality (VR) technology for participatory evaluation (Yu et al., 2017), and proved the applicability and advantages in scenario control for comparative presentations (Iachini et al., 2012; Jiang et al., 2017; Ruotolo et al., 2013). The public's adverse reaction to new wind park projects, due to their noise, can be increased by the insufficient information of the projects. Moreover, it was suggested that the social acceptance would be enhanced through the transparent information and participatory of the public from the initial phase of the planning process (Rafiee et al., 2018; Yeh and Huang, 2014).

This study, therefore, uses an audio-visual survey to investigate how the soundscapes affect the perceived annoyance towards wind parks and to verify some non-aural factors could be considered as statistically significant among them. With the aim of characterizing the soundscapes ambient wind parks, various noise level indices and multidimensional scaling based on the semantic differential technique which were previously used in landscape studies were adopted. As a result of this survey three questions should have been answered:

(1) Effects of sound level on wind parks;

(2) Effects of visual information related to wind parks;

(3) Perception of wind parks in terms of multidimensional indices.

The final aim of this survey was to investigate the realism of the audio-visual simulation method, and how does the aural and visual information influence the realism.

## 3.2 Methods

### 3.2.1 Site selection

Rural landscapes are complex and frequently characterized by various anthropic artificial processing, thus generating a broad diversity of soundscapes with profoundly different characteristics. With the aim of assessing the ambient soundscape of wind parks, a preliminary study with individual sound walks was performed around wind parks in Rostock, which is located in the north-east of Germany and is a popular area for wind parks. As listed in Table 3.1, seven locations with central features of (high traffic flow, birds sound, motorway, human sounds, leisure activities, medium traffic flow and water sound) were selected according to the typologies of soundscapes around wind turbines (WT) in the previous study (Pedersen et al., 2009; Torija et al., 2013).

TABLE 3.1: Physical characteristics at each site. $L_{Aeq}[dB]$: A-weighted sound pressure level; N: loudness; S: sharpness; Fls.: fluctuating strength; R: roughness.

| Site | Sound feature | Category | $L_{Aeq}$ [dB] | N [soneGF] | S [acum] | Fls. [vacil] | R [asper] | Number of WT |
|---|---|---|---|---|---|---|---|---|
| **01** | High traffic flow | Technological sound | 65.3 | 46.06 | 3.21 | 0.017 | 3.24 | 4 |
| **02** | Birds | Natural sound | 39.0 | 1.06 | 1.93 | 0.006 | 0.03 | 4 |
| **03** | Motorway | Technological sound | 52.5 | 10.67 | 1.79 | 0.005 | 1.44 | 10 |
| **04** | Human sounds | Human speeches | 50.2 | 2.85 | 1.46 | 0.005 | 0.24 | 10 |
| **05** | Leisure activities | Human speech | 53.6 | 11.39 | 1.87 | 0.011 | 1.57 | 10 |
| **06** | Medium traffic flow | Technological sound | 41.2 | 9.7 | 1.8 | 0.010 | 1.2 | 5 |
| **07** | Water | Natural sound | 43.7 | 9.7 | 1.8 | 0.010 | 1.2 | 10 |

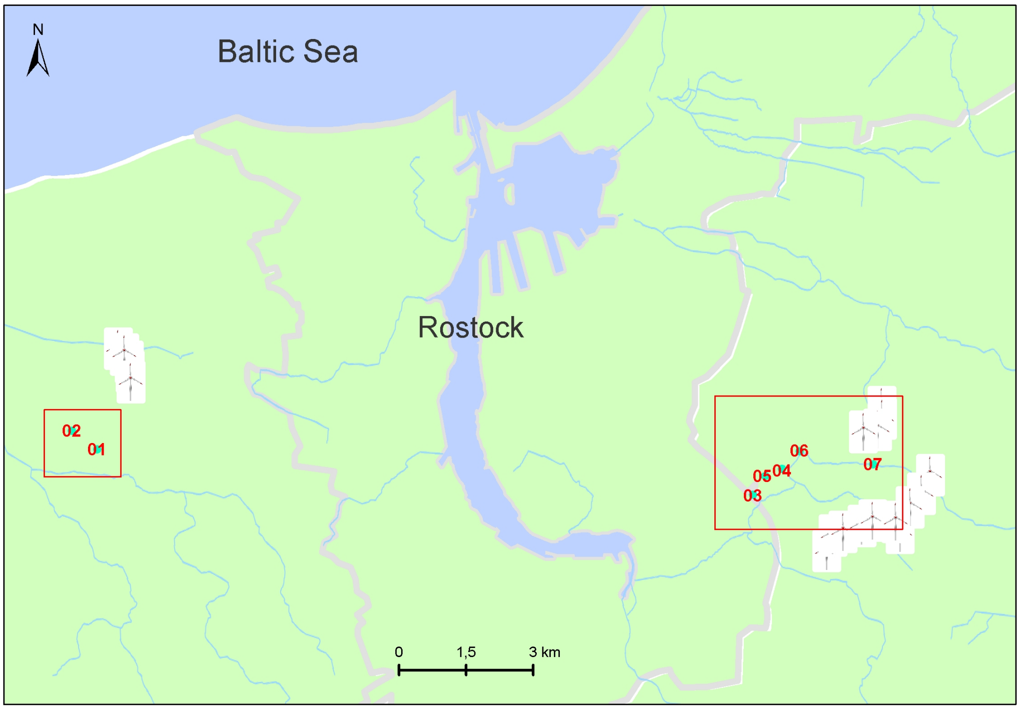


FIGURE 3.1: Recording and measurement locations around wind parks in the Rostock district (north-east Germany).

### 3.2.2 Audio stimuli

Binaural recordings were made with clear weather from 11:00 *am* to 3.00 *pm* using a dummy head with a height of 1.6 *m* and a recorder (DAT 208Ax, Sony) in the selected locations. Wind turbines should be placed at a distance about 800 to 1000 meter away from the residential house according to the local regulations (Plehn, 2012). Jallouli et al. also indicated that wind parks dominate in the visual perception if wind turbines are perceived inner 1 km distance (Jallouli and Moreau, 2009). Thus, the position for recording was placed more than 1000 *m* to the wind park. The recording sites are illustrated in Fig. 3.1. A-weighted sound pressure level ($L_{Aeq}$) were recorded in 3 min. For laboratory experiments, a 32-s audio recording sample of sounds was excerpted from the audio recording. The analysis of four psychoacoustic metrics including loudness (N), sharpness (S), fluctuation strength (Fls.) and roughness (R) was performed through Artemis (Head Acoustics) Software to identify sounds at each site. The characteristics of each site are presented in Table 3.1.

### 3.2.3 Visual stimuli

In this research, the visual stimuli of wind parks based on the selected site were created using Unity 3D, which is a cross-platform game engine and can build scenarios for mobile devices with consideration of the visualization of the built environment as well as the ground of the area (Rafiee et al., 2018). The model of the area and the wind turbines (height: 103 $m$, the diameter of rotor: 105 $m$) were modeled and textured in unity 3D using the 3ds Max modeling software. Both the auditory and visual components of the scenarios were uploaded to make the virtual environment as realistic as possible. The duration and loudness of sounds were normalized before being imported into unity 3D.

### 3.2.4 Experimental design

The primary purpose of the laboratory experiments is to investigate the audio-visual interaction of sound and wind turbine elements on the perception of overall quality of the environment. The experiments consist of three parts: 1) visual-only condition, 2) audio-only condition, and 3) combined audio-visual condition. In total 21 stimuli were created (Fig. 3.2).

In the laboratory experiments, the participants were asked to rate their annoyance scores and acceptance for the wind park in each stimulus using a 7-point Likert scale from “not at all” to “extremely”. Besides the preference test, semantic differential (SD) technique was suggested by previous studies used as a method for connecting public’s feelings at linguistic and psycho-physical levels with the sounds in the landscape and characterizing the soundscape (Cain et al., 2013; Kang and Zhang, 2010). In order to evaluate SD scales of soundscape and landscape, by considering the components found in existing studies, 10 pairs of bipolar adjectives (pleasant-unpleasant, various-monotonous, quite-loud, smooth-rough, calming-agitating, comfortable-uncomfortable, open-closed, natural-artificial, order-disordered, distinct-ordinary) rated in a 7-point scale were selected (Torija et al., 2013; Hong and Jeon, 2013; Nilsson et al., 2012). Participants evaluated each stimulus and were allowed to replay stimuli as many times as they want to answer the questions. Finally, socio-demographic questions were recorded, which includes attributes (“Gender”, “Age”). See also in Table 3.2.

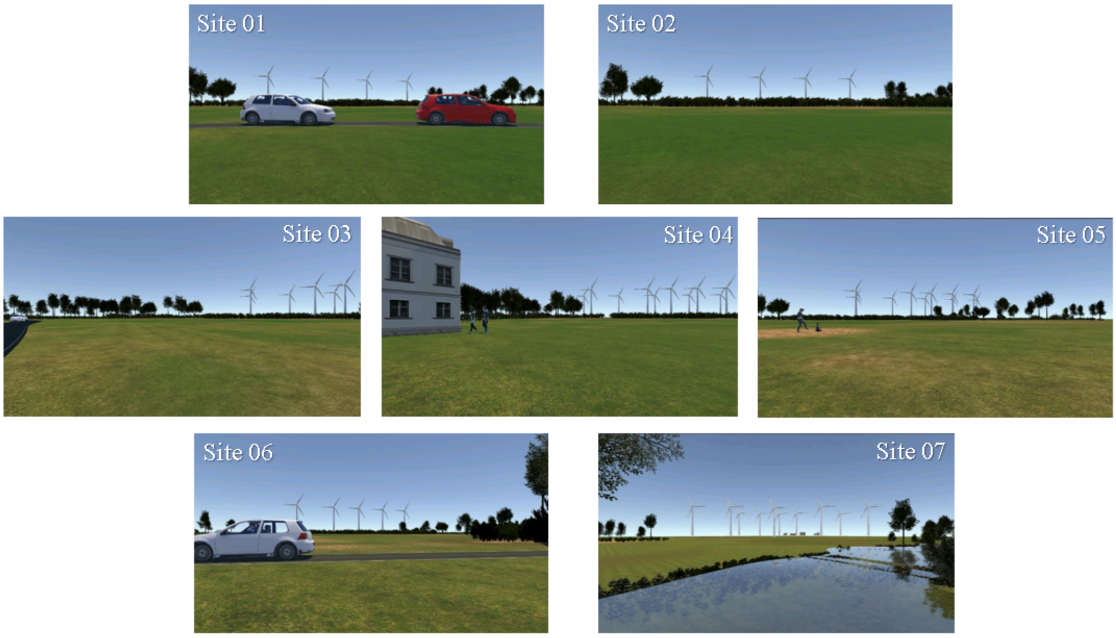


FIGURE 3.2: Selected screenshot of each stimulus for investigated sites.

TABLE 3.2: Index overview of the evaluated variables, the questions, and their scales.

| Index | Indicator |
|---|---|
| | **Perception Question (P)** |
| P1 | Perceived annoyance in the stimuli (Scale: 1-7, from “not at all” to “extremely”) |
| P2 | Preference score for the audio stimuli (Scale:1-7) |
| P3 | Perceived realism of the stimuli (Scale: 1-7, from “not at all” to “extremely”) |
| P4 | Acceptance with the integration of wind turbine in the stimuli (Scale: 1-7, from “not at all” to “extremely”) |
| | **Semantic Differential Test (SD)** |
| SD1-SD10 | 10 pairs of bipolar adjectives: pleasant-unpleasant, various-monotonous, quite-loud, smooth-rough, calming-agitating, comfortable-uncomfortable, open-closed, natural-artificial, order-disordered, distinct-ordinary. (Scale: 1-7, from “not at all” to “extremely”) |
| | **Socio-Demographic Questions (D)** |
| D1-D4 | Gender, Age |

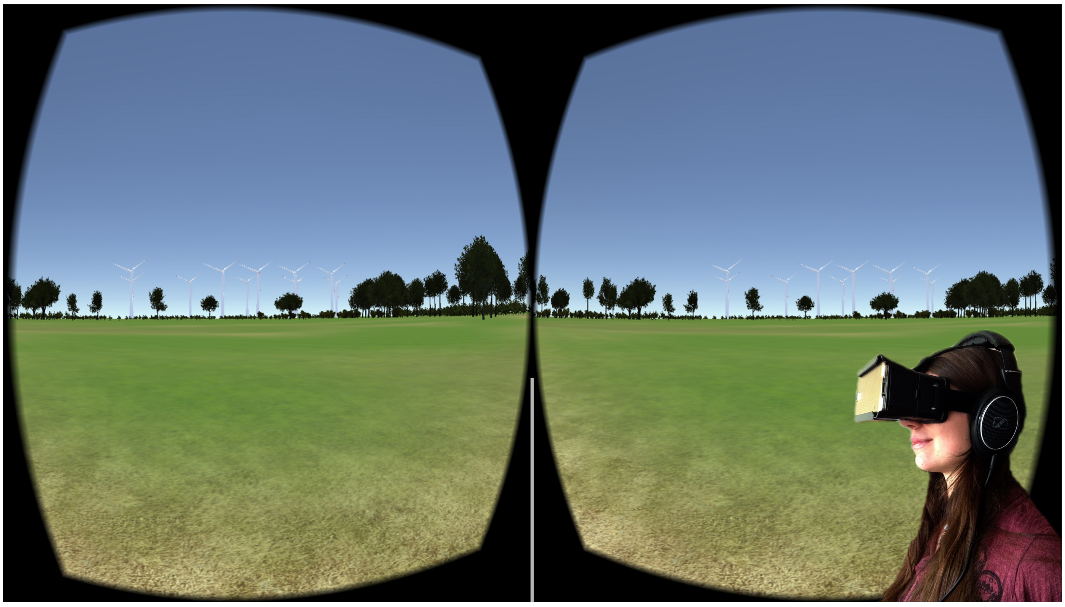

FIGURE 3.3: Simulated 3D wind park in unity, sample viewed aided by Google cardboard and listened with headphones during the experiment.

### 3.2.5 Participants

A total of 40 university students participated in the study of the perception of audio-visual stimuli in laboratory experiments. All participants had normal hearing and regular or corrected to normal vision, had no prior experience with wind parks and all were naive as to the purpose of the experiment. Each participant was tested individually. During the experiments, participants sat in a quiet room ($< 40\ dB$) wearing a Google Cardboard headset with an embedded mobile device (Fig. 3.3). The center points of the scenarios were aligned on the mobile device as represented by unity 3D. Acoustic stimuli were delivered through headphones (Sennheiser HD 598) plugged into the mobile device. The test sound level and the on-site recorded one were closely identified with each other as determined before the start of testing. All testing procedures were carried out between 10:00 and 14:00 $h$ in a quiet room, to avoid any effect of circadian rhythm.

## 3.3 Results and discussion

The general aim of this study was to understand the public responses to wind parks on the landscape. An audio-visual preference survey to investigate the effects of background sounds and non-aural factor on the perception of wind parks and their interaction was used. As described before, in this study the stimuli were included audio only, visual only and combined audio-visual stimuli. In the following, the analysis of subjective responses is conducted. The semantic analysis of the descriptions of the sounds and the correlations between preferences towards wind parks and sound level characteristics are provided below.

### 3.3.1 Effects of sound level on wind parks preference

#### 3.3.1.1 Sound level characteristics

Firstly, a median test was performed to determine the reliability of the differences between the perceived annoyances at each site. The result shows a significant difference for the investigated sites [$chi^2(6, N = 40) = 41.74$; $p < 0.001$]. Secondly, a correlation analysis to determine the background sound characteristics with the perceived sound annoyance was applied under audio-visual condition. According to the results, a strong correlation between the perceived sound and the sound characteristics including the measured sound pressure level ($p < 0.01$), Loudness ($p < 0.05$), Fluctuation strength ($p < 0.05$) and roughness ($p < 0.01$) were found. At last, the correlation coefficients with sound characteristics were calculated and presented below (Table 3.3).

It shows that Loudness explained the most variance (81%), compared to sharpness (52%), fluctuation strength (60%), roughness (80%) and measured sound pressure level (74%). It was suggested that the sound annoyance was increased as the increase of the sound level of ambient sound at wind park sites.

#### 3.3.1.2 Dominant sound information

To further examine how background sound information influences audio-visual wind park environment, overall preference score was compared between condition

TABLE 3.3: The percentage of explained variance calculated using correlation coefficient between the perceived annoyance and background sound characteristics. N: loudness; S: sharpness; F: fluctuating strength; R: roughness; $L_{Aeq}$: A-weighted sound pressure level.

| Sound characteristics vs. perceived annoyance | Explained variance $R^2$ |
|---|---|
| **N** | 0.81 |
| **S** | 0.52 |
| **Fls.** | 0.60 |
| **R** | 0.80 |
| $\mathbf{L}_{Aeq}$ | 0.74 |

visual only and mixed audio-visual. Average general preference scores in two stimuli conditions (visual only vs. audio-visual) were illustrated as shown in Fig. 3.4. The ANOVA on annoyance rates were performed for each condition. As can be seen, the differences in the mean annoyance rates between visual only and audio-visual condition at site 01, site 02, site 05 and site 06 were statistically significant (Fig. 3.4). There was a significant difference in preference score when aural information was added. The sound at site 01 and site 02 was considered as least preferred and most preferred one, respectively. The annoyance scores for the audio-visual stimuli increased at site 01 and decreased at site 02 regards the visual-only stimuli. At site 01 the dominant mechanical sounds could cause an adverse effect on the preference, on the contrary, at site 02 the dominant natural sounds could decrease the annoyance. At site 05, the aural input of human activities increased the annoyance for participants, with the reason that, where human activities may happen, there will be no willingness of wind parks around for participants. At site 06, the noise of traffic enhances the general annoyance score.

The results indicate that the sound influence on annoyance was significant. The addition of natural sounds (birds sounds) could increase the preference of the wind parks environment by a score of 0.75, the addition of mechanical sounds (traffic sounds) and anthropogenic sounds (human sound) could decrease the preference of the wind parks environment by a score of 2.73 and 0.65, respectively. For preference aural-visual combinations with dominant natural sounds would be the most preferred. For preference aural-visual combinations with dominant mechanical sounds would be the least preferred.

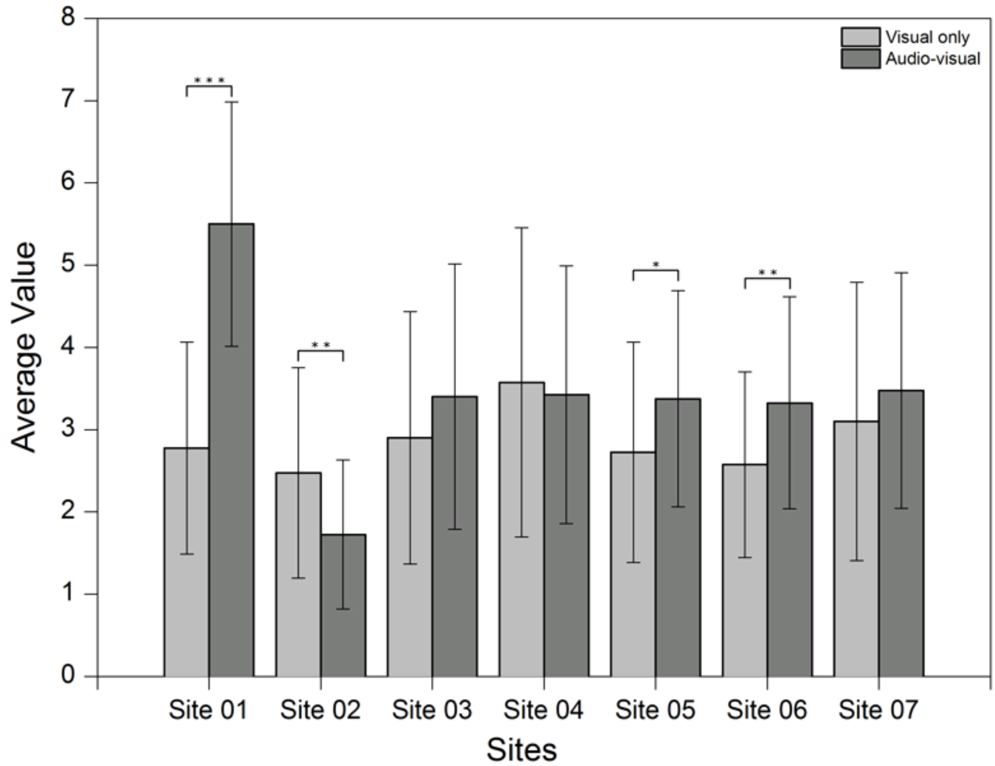


FIGURE 3.4: Annoyance scores in the stimuli of visual only and audio-visual condition at each site, where site 01 was rated as the most annoyed one and site 02 was rated as the least annoyed one in the audio-visual condition. Error bars depict standard error values. *** = $p < 0.001$, ** = $p < 0.01$, * = $p < 0.05$.

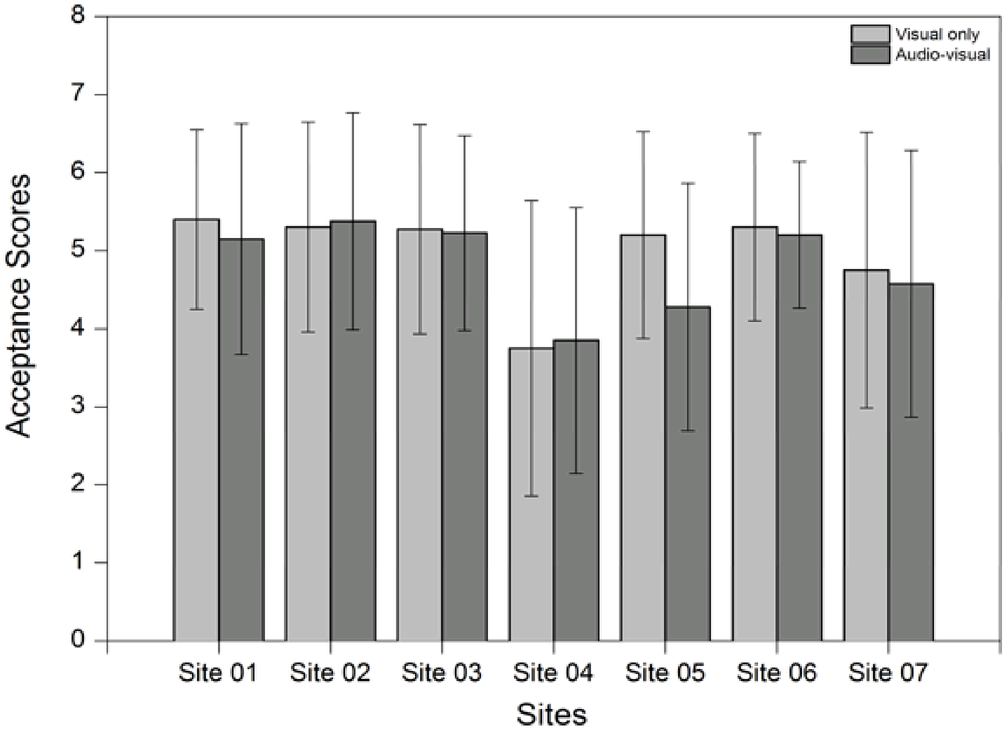


FIGURE 3.5: Acceptance of wind parks in the stimuli of visual only and audio-visual condition at each site, where site 01 was rated as the most annoyed one and site 02 was rated as the least annoyed one in the audio-visual condition. Error bars depict standard error values.

#### 3.3.1.3 Human sounds

To assess the level of acceptance of wind parks in different background sounds, acceptance level towards wind parks in the audio-visual stimulus was rated. The acceptance scores were illustrated with different conditions at each site (Fig. 3.5). It can be seen that all of the investigated sites were considered as a highly accepted area for wind parks except site 04 and site 05 where human sounds and human activities happened.

It can suggest that wind parks project should be avoided being planned in the leisure sites for human beings. It was much accepted that wind energy was a renewable energy which can bring the clean energy for human beings. However, regards to its intrusion to the landscape and communities, the visibility of wind parks to the human eyes need to be restricted.

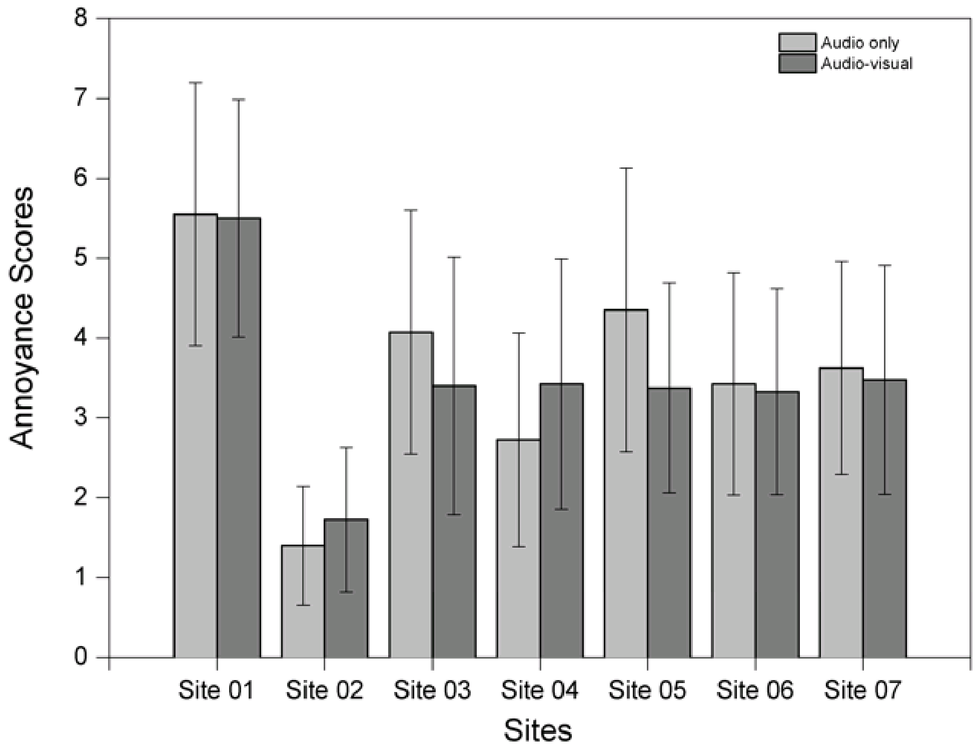


FIGURE 3.6: Average ratings of the sound annoyance at each site in the audio only and combined audio-visual condition, where site 01 was rated as the most annoyed one and site 02 was rated as the least annoyed one. Error bars depict standard error values.

### 3.3.2 Effects of visual information on wind parks preference

In order to study the relation between vision and the subjective measures, the analysis of differences of sound annoyance between audio-only and audio-visual condition was performed. The sound annoyance scores at each site averaged across all subjects is illustrated in Fig. 3.6. The result showed that the most perceived sound was site 02 with birds sound, whereas site 01 with high traffic sound was the least preferred (Fig. 3.6). At audio-visual condition participants most annoyed was site 01 with the high way sound, with a mean annoyance score of 5.5 (SD of 1.48). Compared to that, the mean annoyance score for site 02 with birds sound was 1.7 (SD of 0.9). About the stimuli for site 03, 04, 05, 06 and 07, the related annoyance scores are 3.4, 3.42, 3.38, 3.33 and 3.48 respectively. Overall, their annoyance scores remained similarly. At last, there are no significant differences between audio-only and audio-visual condition at each site ($P > 0.05$).

The impact depends on the sound levels of the simulation, which was suggested to influence the annoyance to wind parks landscape varying in their degree of natural or mechanical sound elements. At last, the results suggested that addition of visual information not affect the sound annoyance in the wind parks landscape. Furthermore, according to the ANOVA analysis, no significant effects were observed for the annoyance scores and the number of wind turbines. The number of wind turbines may not affect the preference of wind parks at a distance of more than 1 *km*.

### 3.3.3 Analysis of soundscape in multidimensional scales

With the purpose of evaluating the key factors which characterize the soundscape around wind parks in multidimensional scales, the SD technique was used, and ten semantic descriptors were selected. Factor analysis of overall results in the condition of audio-visual was carried out to classify the ten semantic descriptors. The method of varimax rotation was selected to extract the orthogonal factors. The criterion factor of eigenvalue was set greater than 1, totally three factors were determined, as shown in (Table 3.4). It can be seen that factor 1 (42.4%) is mainly associated with "sound quality", including smooth-rough; distinct-ordinary, quiet-loud, order-disordered, comfortable-uncomfortable, and calming-agitating. Factor 2 (15.6%) is associated with "relaxation", including open-closed, natural-artificial, and pleasant-unpleasant. Factor 3 (11.4%) is associated with "diversity", composing various-monotonous. These three factors cover the main facets of designing the acoustics of a landscape region. The soundscape quality around wind parks correlates well with the attributes.

After multiple regression analysis, the results demonstrated the dominant factors which best explain the influence of the perception of wind parks in landscape with different ambient sounds. Furthermore, through Pearson's correlation coefficients, the relationships between these factors and sound level characteristics were identified (Table 3.5). Regarding factors obtained from the audio-visual condition, it was indicated that "sound quality" was related to the acoustic characteristics of the loudness and fluctuation strength, as well as annoyance. It can also be seen that the "relaxation" was related to the loudness, roughness, and annoyance. Both "sound quality" and "relaxation" showed a significant correlation with annoyance, which implies the importance of the "sound quality" and "relaxation" in the perception of

TABLE 3.4: Factor analysis of semantic descriptors in the condition of audio-visual. Kaiser-Meyer-Olkin measure of sampling adequacy: 0.725; cumulative 69.487%. Rotation method: varimax with Kaiser Normalization; N= 40.

| Component | Factor 1 (42.4%) | Factor 2 (15.6%) | Factor 3 (11.4%) |
|---|---|---|---|
| **Smooth** | 0.874 | | |
| **Distinct** | 0.858 | | |
| **Quite** | 0.841 | | |
| **Order** | 0.692 | | |
| **Comfortable** | 0.679 | | 0.468 |
| **Calming** | 0.659 | 0.451 | |
| **Open** | | 0.836 | |
| **Natural** | | 0.695 | |
| **Pleasant** | 0.458 | 0.601 | |
| **Various** | | | 0.919 |

TABLE 3.5: Correlation coefficients for semantic factors, four psychoacoustic metrics, sound pressure level and annoyance. $** = p < 0.01$, $* = p < 0.05$.

| Factor | Sound quality | Relaxation | Diversity |
|---|---|---|---|
| **Loudness** | 0.841* | 0.790* | 0.561 |
| **Sharpness** | 0.633 | 0.577 | 0.454 |
| **Fluctuation strength** | 0.756* | 0.672 | 0.294 |
| **Roughness** | 0.916 | 0.843* | 0.571 |
| $L_{Aeq}$ | 0.782* | 0.794* | 0.431 |
| **Annoyance** | 0.964** | 0.971** | 0.593 |

wind parks. At last, there was no correlation between "diversity", acoustical metrics and annoyance.

### 3.3.4 Perceived realism

In this study participants were mostly from the younger generations (18-35 yrs: 98%), they were told to rate the realism of each stimulus in the smartphone mounted into Google cardboard under the condition of visual only and aural-visual.

Most participants rated for higher perceived realism. Table 3.6 shows means and standard deviations for perceived realism for all stimulus under the visual condition

TABLE 3.6: Mean realism of the stimulus for visual only condition and audio-visual used in the experiment and correlations of realism between these two conditions. ** = $p < 0.01$, * = $p < 0.05$.

| **Site** | **Visual condition** | | **Audio-visual condition** | | Pearson Correlation |
|---|---|---|---|---|---|
| | Mean | S.D. | Mean | S.D. | |
| **01** | 5,18 | 1,28 | 5,28 | 1,30 | 0,387* |
| **02** | 4,63 | 1,50 | 4,68 | 1,65 | 0,643** |
| **03** | 4,88 | 1,51 | 5,25 | 1,19 | 0,532** |
| **04** | 4,08 | 1,76 | 4,18 | 1,55 | 0,352* |
| **05** | 5,05 | 1,15 | 3,98 | 1,54 | 0,145 |
| **06** | 4,83 | 1,38 | 5,05 | 1,20 | -0,041 |
| **07** | 4,28 | 1,60 | 4,30 | 1,68 | 0,368* |

and audio-visual condition, as well as the correlation of perceived realism between them.

It demonstrates that most participants (60%) rated the visual stimuli as relatively good and realistic with rating scores above 5 ($Mean = 4.73$; $S.D. = 1.43$). More than the half of the participants (59%) rated aural-visual stimuli with rating scores above 5 ($Mean = 4.67$; $S.D. = 1.52$). The lowest perceived realism correspond to site 04 and site 05 with speeches under an audio-visual condition with mean rating scores around 4 with main comments of “incongruent of sound and visual content”. The highest perceived realism corresponds to site 01 and site 03 with traffic sounds under an audio-visual condition with rating score above 5. There were also comments on using VR methods via smartphone to stimulate the scenery of wind parks, like “innovative”, “sense of participation” and “incongruence with aural-visual simulation”. Results of the experiment show the relatively high potential of VR on a smartphone to display virtual aural and visual landscape environment, cheaply and conveniently. Realism is influenced strongly by the congruency of visual and sound content. The incongruent of visual and sound content can lead to low realism ratings.

## 3.4 Conclusions

Investigating how new infrastructure projects, such as wind parks impact the quality of people living, is an essential factor in landscape planning. Various factors need to be defined and indecently investigated regards the case of wind parks. In this study, the audio-visual simulation was used to evaluate soundscape ambient wind parks without taking into account the noise of wind turbines. The background sounds and non-aural factor on the perception of wind parks and interaction between the aural and visual information were investigated.

According to the results, the background sound level especially sound pressure level and roughness were strongly correlated with wind parks preference. However, no significant correlation was achieved between visual information and the annoyance scores towards wind parks. The visual information may not affect wind parks preference at a distance of more than 1 $km$. Furthermore, the analysis of soundscape in multidimensional scales indicated the importance of the “sound quality”, “relaxation” and “diversity” concerning preference of the environment around wind parks. Among them, factors of “sound quality” and “relaxation” were strongly correlated with background sound level characteristics including loudness, fluctuation strength, roughness, sound pressure level and perceived annoyance. At last, it was suggested that the realism of the audio-visual simulation strongly influenced by the congruency of visual and sound content. The audio-visual simulation on smartphone provides a technology in intuitive and interactive ways for participatory evaluation of wind park soundscape. It can help to study progressive the potential public disturbance related to a specific wind park project and enhance the social acceptance.

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# Chapter 4

# Validity of VR technology on the smartphone for the study of wind park soundscapes

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# Validity of VR Technology on the Smartphone for the Study of Wind Park Soundscapes

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**Abstract:** The virtual reality of the landscape environment supplies a high level of realism of the real environment, and may improve the public awareness and acceptance of wind park projects. The soundscape around wind parks could have a strong influence on the acceptance and annoyance of wind parks. To explore this VR technology on realism and subjective responses toward different soundscapes of ambient wind parks, three different types of virtual reality on the smartphone tests were performed: aural only, visual only, and aural–visual combined. In total, 21 aural and visual combinations were presented to 40 participants. The aural and visual information used were of near wind park settings and rural spaces. Perceived annoyance levels and realism of the wind park environment were measured. Results indicated that most simulations were rated with relatively strong realism. Perceived realism was strongly correlated with light, color, and vegetation of the simulation. Most wind park landscapes were enthusiastically accepted by the participants. The addition of aural information was found to have a strong impact on whether the participant was annoyed. Furthermore, evaluation of the soundscape on a multidimensional scale revealed the key components influencing the individual's annoyance by wind parks were the factors of "calmness/relaxation" and "naturality/pleasantness". "Diversity" of the soundscape might correlate with perceived realism. Finally, the dynamic aural–visual stimuli using virtual reality technology could improve the environmental assessment of the wind park landscapes, and thus, provide a more comprehensible scientific decision than conventional tools. In addition, this study could improve the participatory planning process for more acceptable wind park landscapes.

**Keywords:** noise annoyance; virtual reality; wind park perceptions; soundscape; aural visual interaction

## 1. Introduction

Wind parks are viewed as the top investment objective in renewables according to European Union (EU) targets, leading to the rapid increase of wind farms across Europe. The installation of new renewable energy in the landscape has reached a critical mass, and is becoming a great issue in Germany and all over Europe [1]. According to a recently accepted survey about energy technology, there were significant differences between the acceptance of wind parks on the national and local levels. This was mainly because of the landscape modification after constructing wind farms [2]. In addition, not-in-my-backyard (NIMBY) syndrome increased the difficulty of the local acceptance of wind farms. The lack of the public's participation in wind park projects has been a key issue for successful wind energy planning, and the EU has encouraged transparency and early involvement in wind energy projects [3]. The procedure for evaluating design from human-centered perspective and the gap between technical potential and social needs should be studied [4].

In contrast to the linguistic methods, using direct presentation of the wind park landscape and digital landscape visualization could improve public participation and enable to receive more responses related to wind energy projects. In addition, the development of technology could enable the designers of landscapes and urban areas to use digital visualization tools for landscape design, planning, and management. Currently, digital landscape visualization is becoming the clearest approach that expresses the designs and planning processes from designers. However, as it is lacking in the demonstration and illustration with regards to depth perception, rendering images, and physical models, traditional landscape visualization does not fully meet the requirements of fast-developing landscapes. For example, traditional visualization media, such as the geographic information system (GIS) maps and photo-realistic images, were difficult for participants to understand. They also might cause confusions or errors in their orientation recognizing [5,6]. Today, researchers are beginning to represent the future landscape in a controlled laboratory by using immersive virtual reality (VR) technologies for participants. In related field work, VR has verified that it can effectively reproduce visual and aural information for participatory evaluation [7–10].

Although the visual images are the dominant human sensory for landscape perception, they only provide partial information and lack another important sensory component: sound information. Thus, a more comprehensive method should be encouraged to evaluate participants' annoyance from the landscape constructions. Manyoky conducted an investigation on the effect of the addition from ambient sounds to the simulations of the perceived realism [6,11]. Unlike traditional demonstration methods, visual–aural stimuli in VR simulations with head orientation can leave users with a feeling of human perception. In addition, the adoption of these technologies for smartphones can enable more members of the public to participate in landscape designs by providing the information via the smartphone, which has been rapidly enhanced in the last decade [12]. The combination of VR technologies of smartphones and audio rendering effects make it possible to perform a new experiment for conducting a reasonable environmental assessment. So far, no studies are made to validate VR simulations of wind park projects on smartphones. This can be demonstrated with applications, with the aid of the Unity 3D game engine. This technology is easily accessible and cost-favorable, and helps the public to communicate with wind park projectors and encourages them to participate, which can help the designers to make educated decisions.

It was also interesting to find that the attitude toward noise of wind turbines has no significant correlation with subjective annoyance [7–10]. This suggested a phenomenon, generally, that people have a bad impression of the noise of wind turbines in mind from first sight, even if they do not have any real experience with wind turbines in the landscape. The noise of wind turbines was masked by surrounding natural sounds or traffic sounds in the background, and presentation of soundscape ambient wind parks could give them different impressions, thus modifying their responses as expected. In addition, the combination of motion and sound were reported to be important for a reliable evaluation of the landscape [13]. Due to the fast developments of computer digital technology, interactive and 3D visualizations can offer new opportunities to improve public communication in the planning stage. The VR technology linking acoustic information enables landscape visualization with a high level of realism, based on geodata with added detailed 3D models and dynamic processes.

The purpose of this study is to apply VR technology pairing aural information to explore the impact of sound on the wind park landscapes. Empirical evidence of the contribution was provided to perceived realism and subjective responses of VR simulations on smartphones. The realism and the relevant factors, i.e., preference ratings and soundscape characteristics in the context of wind parks, were further explored. This study starts with ratings of the realism of VR simulations. Then individuals' general responses (acceptance or annoyance) were evaluated, and the aural–visual interactivity was thus explored. Finally, the soundscape characteristics were explored and compared with the ratings of VR realism.

## 2. Materials and Methods

### 2.1. Site Selection

Rural landscapes are multiform, and usually generate varied soundscapes with extremely different attributes. To validate the VR simulation on the smartphone for the study of wind park soundscapes, main soundscapes around wind parks need to be explored. Thus, sites with typical soundscapes of ambient wind parks were selected based on the previous studies [14,15]. As a result, seven sites with main characteristics (site 1: high traffic flow, site 2: bird sounds, site 3: motorway, site 4: human sounds, site 5: leisure activities, site 6: medium traffic flow, and site 7: water sounds) were chosen for the case study (Table 1).

After the selection of expected sites, aural and visual materials were prepared for laboratory experiments as described in the following paragraphs, to develop related VR simulations on a smartphone.

**Table 1.** Elements in the scenarios at each site.

| | Sound Features | Visual Features | | | | | | | | Description | $L_{Aeq}$ [dB] |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Sites** | | **Wind Turbines** | **Cars** | **People** | **Stream** | **Road** | **Dwellings** | **Trees** | **Sky** | | |
| **Site 1** | High traffic flow | × | × | | | × | | × | × | Main Avenue with high road traffic flow with a large number of vehicles. | 65.3 |
| **Site 2** | Birds | × | | | | | | × | × | Location situated in natural environment isolated from sounds of human activity, sounds dominated with bird sounds. | 39 |
| **Site 3** | Motorway | × | × | | | × | | × | × | Location situated in the motorway. | 52.5 |
| **Site 4** | Human sounds | × | | × | | | × | × | × | Location situated in a residential area, sounds included people talking. | 50.2 |
| **Site 5** | Leisure activities | × | | × | | | | × | × | Location situated near residential area, with sounds of outdoor activities. | 53.6 |
| **Site 6** | Medium traffic flow | × | × | | | × | | × | × | Location situated in a residential area with medium road traffic flow. | 41.2 |
| **Site 7** | Water | × | | | × | | × | × | × | Location situated in natural environment, with sounds from stream. | 43.7 |

### 2.2. Aural and Visual Materials

Firstly, a preliminary site survey around wind parks was conducted in the selected seven sites. In order to link ambient sounds with the VR landscape model and avoid complexity of the task, the related binaural recordings of ambient wind parks were made with clear weather from 11:00 a.m. to 3.00 p.m. using a dummy head with a height of 1.6 m and a recorder (DAT 208Ax, Sony (Tokyo, Japan)) at selected viewpoints of these sites. A-weighted sound pressure levels ($L_{Aeq}$) were measured in 3 min at each viewpoint (Table 1). Each recording point was placed more than 1000 m from the wind park in consideration of the local regulations regarding distance limitations to residential houses [16]. Thus, the noise of wind turbines was not considered in this study.

Subsequently, visual scenarios were made for each site in Unity 3D with the help of 3ds Max modeling software. The modeling procedure and tools used for the laboratory experiment are illustrated in Figure 1. Visual scenarios were created to approach the real landscape, which contained the visual features of each site listed in Table 1. To reach this task, a digital elevation model (DEM), also named height maps, was used to generate the terrain. The digital elevation model recorded the details of height elevation, and the basic ground in the simulated landscape was created to approach the real site. Textures including vegetation, roads, and other elements were then draped over the digital terrain with the help of Photoshop program. As the simulation progressed, the initial ground was covered by textures representing grass and roads etc. Other digital assets, including trees, cars, wind turbines, and other objects in 3D file formats were inserted into the defined areas with the help of the 3dx Max modelling program. The detailed modeling was mostly modeled by hand. With the aim of creating simulations that are close to the wind turbine in reality, the object of wind turbines was required to be dynamic, avoiding the negative effects of static wind turbines [17]. Thus, the scripting for dynamic wind turbines was built on Mono, which was an open-source implementation of the .NET Framework. The basic 3D models inserted above were matched with each actual survey site (wind turbines, cars, people, stream, trees, grass, road, house, sky, etc.) (Table 1 and Figure 2).

Finally, the recorded onsite aural data were uploaded into the unity 3D audio system. Both the aural and visual components of scenarios were combined to make the VR environment as realistic as possible. Unity, herein, supported the deployment to varied platforms. Within this study, a smartphone was used due to its low cost and convenient usage. The tests composed three conditions at seven sites: (1) visual only condition; (2) aural only condition; and (3) combined aural–visual condition. In total, 21 stimuli were thus generated.

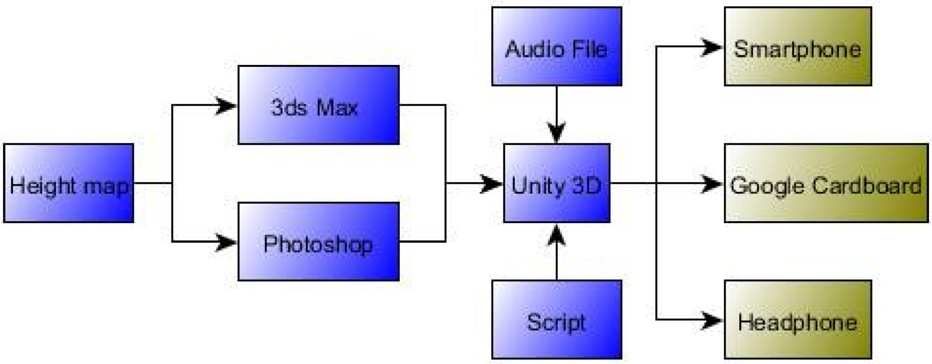


**Figure 1.** Modeling procedure and tools used.

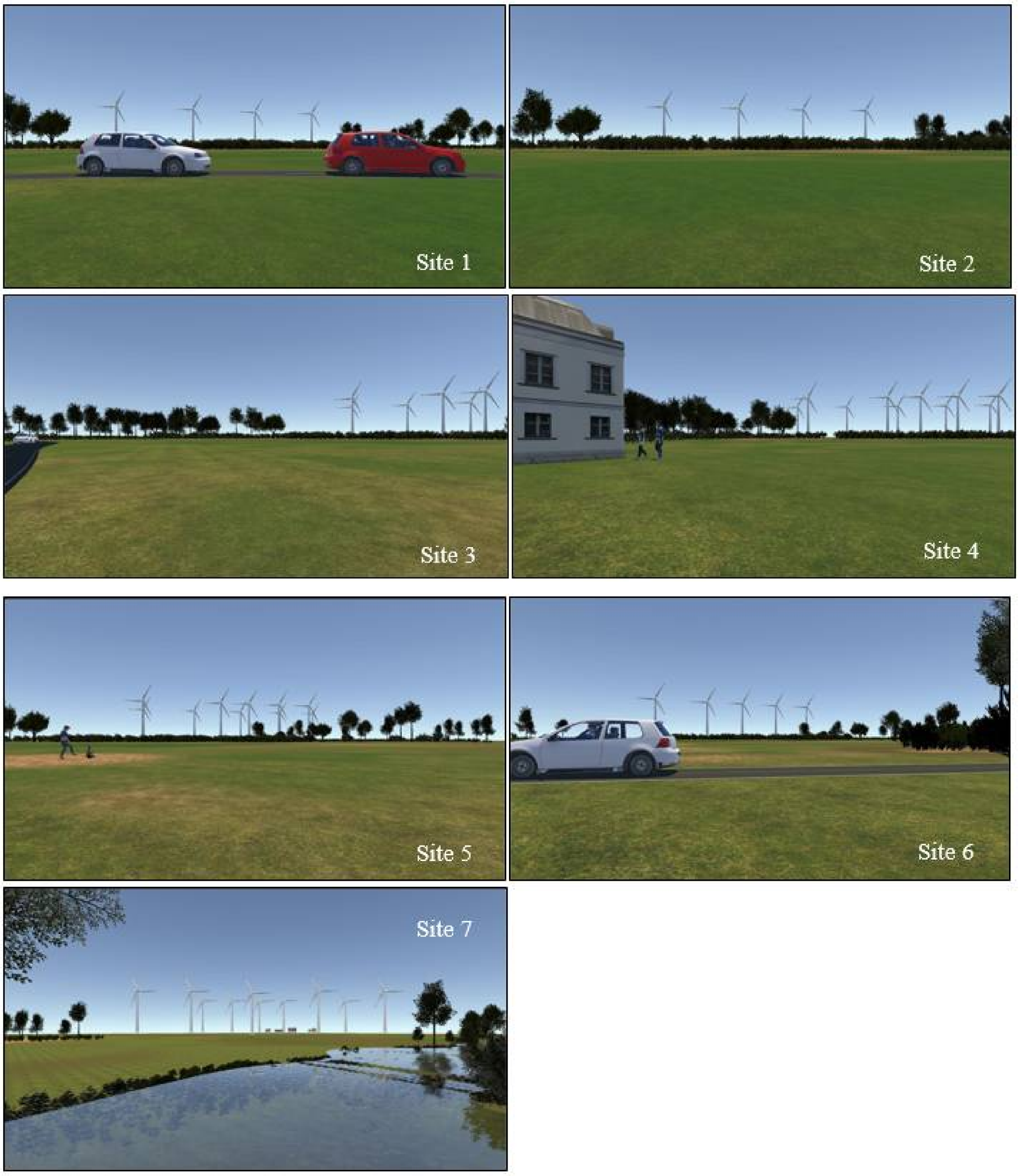


**Figure 2.** Selected snapshots from the aural–visual simulation at each site, detailed descriptions of each site were listed in Table 1.

### 2.3. Measures of Subjective Evaluations

To explore the impact of the aural–visual VR scenarios on participants, a questionnaire on the annoyance from wind parks, the realism, and semantical differential tests were assessed. Among them, the annoyance and the realism were rated from "not at all" to "extremely" on a 7-point Likert scale (1 = "not at all", 2 = "low", 3 = "slightly", 4 = "neutral", 5 = "moderately", 6 = "very" and 7 = "extremely"). The semantical differential technique was proposed by former researchers as a test method for linking people's feelings at linguistic and psychophysical levels with the soundscape within multidimensional scales [18–20]. The bipolar adjectives were used for the semantical differential test to characterize the soundscape: pleasant/unpleasant, various/monotonous, quiet/loud, smooth/rough, calming/agitating, comfortable/uncomfortable, open/closed, natural/artificial, order/disordered, and distinct/ordinary were rated on a 7-point scale (Figure 3).

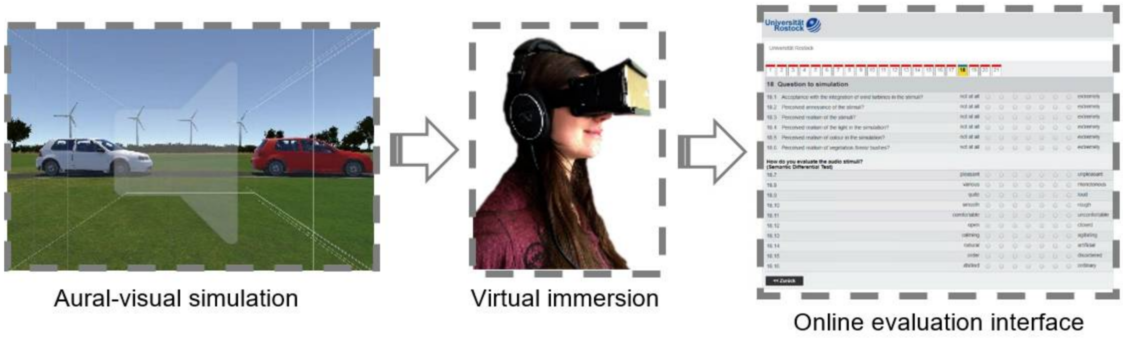


**Figure 3.** The experimental setting of the aural–visual assessment in a controlled laboratory; participants rated 21 stimuli in total through cardboard/headphones and completed the responses of the online evaluation system.

### *2.4. Participants and Experimental Precedure*

For data collection from individuals for validation of the VR simulations on soundscape analysis of wind parks, a total of 40 volunteer students and staff from University of Rostock (18–35 years: 98%, men: 57.5%, women: 42.5%) participated in the aural–visual assessment of wind parks. All of them had normal hearing and vision. Participants sat in a quiet room (<40 dB) and experienced the aural–visual stimuli in VR simulations. They wore a Google Cardboard headset with an embedded smartphone presented via unity 3D platform. This headset allows the scene view to move in an immersive 360° in response to head movements, and enables a three-dimensional audio environment with the headphone plugged into the smartphone device. Therefore, they could watch the wind park scenarios in VR and experience a similar reality. Aural stimuli were delivered through the headphone (Sennheiser HD598) plugged into the smartphone. The test sound level and the on-site recorded one were set closely to each other before the start of the test.

The experimental questions were presented to the participants on a laptop computer, using EvaSys V7.1 (evaluations system of the University Rostock) (Figure 3). Within this interface, each simulation was performed in 32 s, and the test order was randomized in each assessed condition. Participants evaluated each simulation and were allowed to experience the simulation as many times as they wanted in order to complete the evaluation questions.

## 3. Results and Discussion

### *3.1. Realism of VR Simulations*

In the visual only and aural–visual combined condition, participants evaluated their realism on a 7-point rating scale. Results showed a highly perceived realism for most participants. Figure 4 shows means and standard deviation of rated realism for all scenarios under the visual only and aural-visual conditions. Perceived realism was mostly (60% of the participants) rated as moderately realistic and realistic under the visual only condition, with rating scores above 5 (close to very realistic). More than half of the participants (59%) rated aural–visual scenarios with scores above 5. The worst realistic scenarios corresponded to site 4 and site 5 with human voices due to "incongruence of human sound and visual content", according to their comments. Scenarios at site 1 and site 3 with road traffic sound rating scores above 5 were rated as the most realistic. Therefore, with the aid of VR, the aural–visual interactive and dynamic simulations can create scenarios with a high level of realism. The interactivity and dynamics of the virtual environment could support the public's understanding of wind park projects.

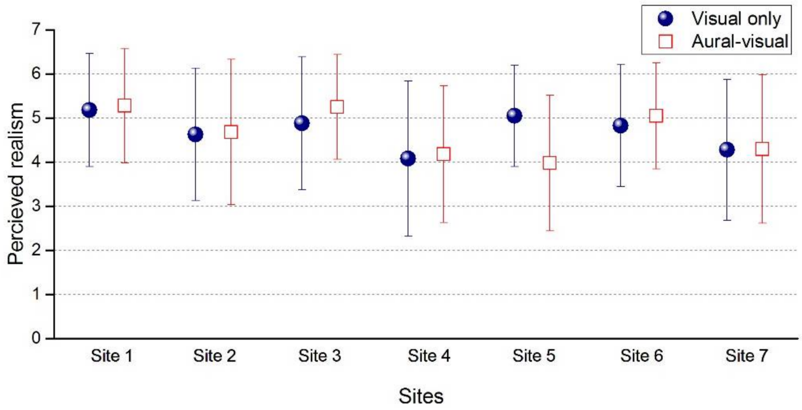


**Figure 4.** The rated realism of scenarios under visual only and aural–visual conditions at each site.

To improve the simulations, participants rated the seven simulations in the aspects of light realism, color realism, and vegetation realism. Results for each site are listed in Table 2. A significant correlation was found between total realism, light realism, color realism, and vegetation realism ($p < 0.001$). The more realistic the light realism, color realism, and vegetation realism were, the more realism there was in total. The analysis of variance (ANOVA) tests on perceived realism were calculated for different realism metrics (light realism, color realism and vegetation realism) at seven sites. Results confirmed a significant main effect on the realism metrics ($F$ (3, 39) = 5.079, $p < 0.01$).

**Table 2.** Mean realism and standard deviation in different realism metrics (light realism, color realism, and vegetation realism) under visual only condition.

| **Sites** | **Aspects** | **Realism** | |
|---|---|---|---|
| | | **Mean** | **SD** |
| **Site 1** | Light | 5.1 | 1.03 |
| | Color | 4.75 | 1.26 |
| | Vegetation | 4.65 | 1.39 |
| | Total realism | 5.18 | 1.28 |
| **Site 2** | Light | 5.03 | 1.16 |
| | Color | 4.78 | 1.37 |
| | Vegetation | 4.48 | 1.60 |
| | Total realism | 4.63 | 1.50 |
| **Site 3** | Light | 4.88 | 1.32 |
| | Color | 4.75 | 1.45 |
| | Vegetation | 4.55 | 1.71 |
| | Total realism | 4.88 | 1.51 |
| **Site 4** | Light | 4.83 | 1.38 |
| | Color | 4.75 | 1.30 |
| | Vegetation | 4.58 | 1.52 |
| | Total realism | 4.08 | 1.78 |
| **Site 5** | Light | 5.1 | 1.17 |
| | Color | 4.8 | 1.24 |
| | Vegetation | 4.68 | 1.53 |
| | Total realism | 5.05 | 1.15 |
| **Site 6** | Light | 4.9 | 1.32 |
| | Color | 4.63 | 1.46 |
| | Vegetation | 4.3 | 1.60 |
| | Total realism | 4.83 | 1.38 |
| **Site 7** | Light | 5.05 | 1.22 |
| | Color | 4.8 | 1.26 |
| | Vegetation | 4.43 | 1.68 |
| | Total realism | 4.38 | 1.69 |

### 3.2. Aural–Visual Interactions in VR Simulations

In the visual only and aural–visual combined conditions, participants evaluated their acceptance on a 7-point Likert scale. The mean values of the acceptance evaluated for each site for 40 participants are presented in Figure 5. The evaluation of acceptance of wind parks were conducted in two conditions (visual only and aural–visual conditions), since the aural stimulus was not synthetic but came directly from original binaural recordings. This study intended to avoid confusion and fatigue on the part of the participants in rating these parameters. The data were calculated by a two-way ANOVA test in these two conditions, and seven sites were independent of each other. Acceptance was the dependent variable.

Results showed a statistically significant main effect located at the site ($F$ (6, 39) = 11.75, $p < 0.001$). No significant main effect was found between two conditions. It could be seen that all of the investigated sites were rated as highly accepted areas for wind parks. This included site 1, with rated acceptance by a score of 5.15; site 2, site 3, site 6, site 7 were 5.38, 5.23, 5.2, and 4.58, respectively. Of all the sites, site 4 and site 5, where human activities took place nearby, had scores of approximately 4, and were rated the least accepted sites.

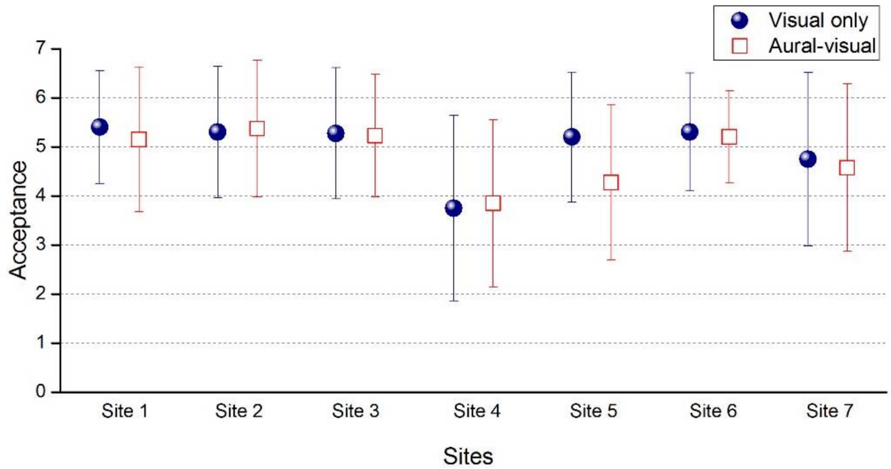


**Figure 5.** Acceptance under visual only and aural–visual conditions at each site.

The results indicated that participants had a relatively high acceptance for wind parks at rural sites, but the addition of human activities could decrease the acceptance for wind parks. People might find wind parks to be clean and meaningful constructions when they were "not in my backyard". Otherwise, wind turbines might be considered to be ugly and annoying constructions, which converted the natural recreational areas to industrial sites. This study could suggest that planning of wind parks must be restricted near sites of human activities.

Furthermore, participants rated the general annoyance of the simulation under aural only, visual only and aural–visual combined conditions. The ANOVA annoyance test scores were calculated for three conditions (aural only, visual only, and aural–visual conditions) at seven sites. Results showed a statistically significant main effect was in the condition ($F$ (2, 39) = 20.00, $p < 0.001$) and sites ($F$ (6, 39) = 77.49, $p < 0.001$), and also a significant interaction effect was in the condition versus sites ($F$ (12, 43) = 22.10, $p < 0.001$). Mean general annoyance scores in three conditions were plotted in Figure 6. It was found that annoyance at most sites (site 1, site 2, site 6, and site 7) in the aural–visual condition was closer to the results of the aural only condition than the visual only condition. This result illustrated the fact that the addition of the visual information did not significantly change the perceived annoyance, which may be because of the similarity of the rural environment. In addition, the presentation of visual simulations was not as complex as that of the real site, because detailed visual modeling by hand is time consuming. In this study case, aural information was more influential than visual information with regards to the wind park landscapes.

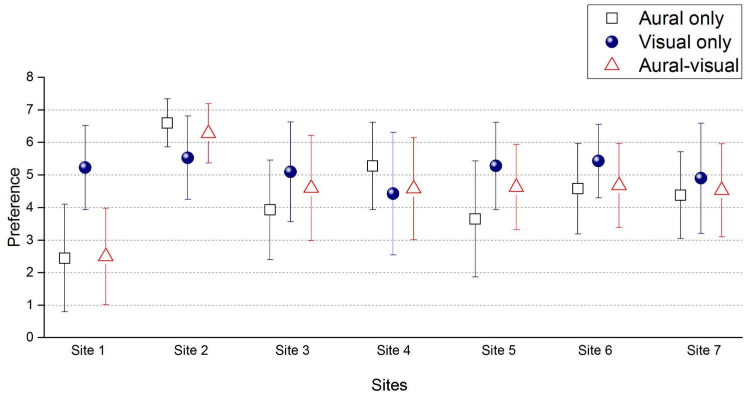


**Figure 6.** Perceived annoyance with wind parks under aural only, visual only, and aural–visual conditions at each site.

As could be seen, the addition of aural information decreased the annoyance with the simulation for most sites, except site 2 with dominant natural sounds (birds). Conversely, a significant decrease was shown at site 1 with dominant mechanical sounds (traffic). Finally, site 2 with dominant bird sounds was the most preferred site, and site 1 with dominant traffic noise was the least preferred one. Results indicated that the aural information played an important role for the annoyance of the wind park simulation. Further the addition of human sounds, traffic sounds, or water sounds in the rural region had a negative influence on the preferences of wind parks, while the addition of bird sounds brought a positive effect to the preferences.

The relationship between realism and annoyance was analyzed; however, there was no significant effect. The reason was that, in the specific wind park projects, when the realism of landscape was relatively strong, the primary interactive factor for the annoyance of wind parks could be another important factor, such as the sound pressure level [21]. Overall, the addition of sound increased the realism of the simulations; however, incongruence of the aural and the visual information could have a strong negative impact on it.

### 3.3. Soundscape in Multidimensional Scales in VR Simulations

In the VR method in the soundscape study, perceived realism was further explored with soundscape factors. Therefore, a method of the multidimensional scales was used to assess the soundscape at linguistic and psychophysical levels, and determined how the different semantical scales were linked to one another. According to the semantical descriptors, participants rated the seven scenarios. The mean ratings of the bipolar adjectives of the semantical description are shown in Figure 7. Site 3, site 4, site 5, site 6, and site 7 remain in the middle of the radar circle, except the metric of open/close. However, site 1 located in the outer circle and site 2 located close to inner circle of the radar plot are clearly seen. At the same time, as described above, site 1 with dominant traffic sounds and site 2 with dominant natural bird sounds were rated as the least preferred sites and most preferred sites, respectively. These results are somewhat consistent. They confirm the importance of the semantical characteristics of an ambient soundscape on perception of wind park landscapes. The relationship between the semantical metrics and perceived annoyance will be discussed in the coming paragraph. Furthermore, site 1 was found to be quiet, distinct, natural, open, calming, smooth, and comfortable for the participants, while site 2 was found to be the opposite of site 1. This could be explained by the fact that people prefer landscapes with bird sounds to those with traffic sounds.

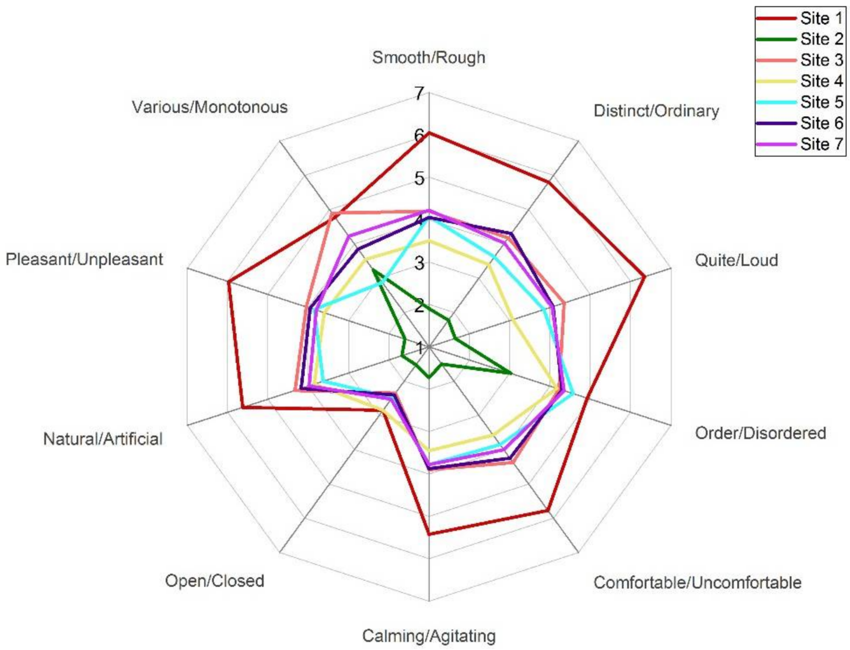


**Figure 7.** Mean ratings of the simulations for bipolar adjectives of soundscape semantic description.

The principal component analysis (PCA), a statistical method was proposed to explore communalities in collected soundscape semantical data, and Kaiser–Meyer–Olkin (KMO) was applied within PCA to verify the adequacy of the data and the factor loadings [18–20,22]. The PCA with varimax rotation was thus chosen to extract the orthogonal factors (Table 3). Three factors were determined to explain their variance. Component 1 was extracted to explain 42% of the variance, which had high positive loadings for "smooth/rough," "distinct/ordinary," "quiet/loud," "order/disorder," "comfortable/uncomfortable," and "calming/agitating." This component could represent "calmness/relaxation" as demonstrated by former researchers [20]. Component 2 was extracted to explain 16% of the variance, which had high positive loadings for "open–closed," "natural–artificial" and "pleasant–unpleasant." Thus, it could be relevant to "naturality/pleasantness." Component 3 was extracted to explain 11% of the variance, and it had high positive loadings for "various/monotonous," which could be related to "diversity." These three components retained orthogonality, which also explains 69% of the variability in the original ten dimensions.

**Table 3.** Principal component analysis (PCA) of the bipolar adjectives of soundscape semantical description (Eigenvalue > 1, Kaiser–Meyer–Olkin (KMO) index = 0.725, Bartlett's test of sphericity $p$ = 0.000, N = 40).

| Component | Component 1 (42.4%) | Component 2 (15.6%) | Component 3 (11.4%) |
|---|---|---|---|
| Smooth–rough | 0.874 | | |
| Distinct–ordinary | 0.858 | | |
| Quite–loud | 0.841 | | |
| Order–disorder | 0.692 | | |
| Comfortable–uncomfortable | 0.679 | | 0.468 |
| Calming–agitating | 0.659 | 0.451 | |
| Open–closed | | 0.836 | |
| Natural–artificial | | 0.695 | |
| Pleasant–unpleasant | 0.458 | 0.601 | |
| Various–monotonous | | | 0.919 |

After factor analysis, the strongest factors for explaining the impact on the annoyance with wind park landscapes were achieved. In addition, further analysis of Pearson's correlation among these factors, perceived realism, annoyance, and psychoacoustic factors were conducted and listed in Table 4. Mean perceived realism in the aural–visual condition and four psychoacoustic metrics including loudness, sharpness, fluctuation strength, and roughness, were obtained through Artemis (Head Acoustics) Software, and were applied for the correlation analysis. Results showed that "diversity" was related to the perceived realism. "Diversity" of soundscape had a stronger impact on the perceived realism than the others. In order to enhance the reality of the landscape, varieties of soundscapes should be considered. Results also indicated that the factors "calmness/relaxation" and "naturality/pleasantness" were correlated to psychoacoustic metrics "loudness" and "fluctuation strength." Annoyance with wind parks was significantly correlated to "calmness/relaxation" and "naturality/pleasantness" of the soundscape, marking the importance of "calmness/relaxation" and "naturality/pleasantness" in the evaluation of wind park landscapes.

**Table 4.** Correlation coefficients for semantical factors, psychoacoustic metrics, annoyance and perceived realism.

| Factor | Calmness/Relaxation | Naturality/Pleasantness | Diversity |
|---|---|---|---|
| Perceived realism | 0.401 | 0.339 | 0.759 * |
| Loudness | 0.841 * | 0.790 * | 0.561 |
| Fluctuation strength | 0.756 * | 0.672 | 0.294 |
| Roughness | 0.916 ** | 0.843 * | 0.571 |
| $L_{Aeq}$ | 0.782 * | 0.794 * | 0.431 |
| Annoyance | 0.964 ** | 0.971 ** | 0.594 |

** = $p < 0.01$. * = $p < 0.05$.

## 4. Conclusions

One of the key challenges in the communication of landscape design proposals is the adequacy of simulation. The virtual environment of this study provided a fixed viewpoint in which the user could explore the simulated environment in 360 degrees. The addition of sound information on the simulated virtual environments contributed to a sufficient evaluation of wind park landscapes.

Most of these VR simulations on the smartphone were rated from relatively good realism to high realism under the aural–visual condition. The developed aural–visual VR simulations on the smartphone is thus proved to be a valid method for the study of wind park soundscapes. In addition, it was found that light, color, and vegetation realism could enhance the simulation experience.

The ratings of acceptance of wind parks indicated the high agreements with conducting wind park projects, but the addition of human activities could decrease the acceptance of wind parks. It was found that the aural information played an important role in perceived annoyance, and the addition of human sounds, traffic sounds, or water sounds in the rural region had a negative influence on the preferences for wind parks. There was a relatively large number of residents against wind park projects. Using VR technology to supply the public with a virtual environment of the wind park landscape could be considered the primary means of communication with the public.

Furthermore, results of soundscapes in multidimensional scales confirmed the importance of the semantical characteristics of ambient soundscapes on perception of wind park landscapes. The strongest components for evaluation of wind park landscapes were "calmness/relaxation" and "naturality/pleasantness." In addition, "diversity" of the soundscapes were found to have a strong impact on the perceived realism.

The results could be used for comparison for other validation studies based on aural–visual interaction simulations [23]. This method with the addition of spatial sound information could contribute significantly in enhancing the environmental assessment of the wind park landscapes, and thus provide a more comprehensible scientific decision than conventional tools, such as GIS maps and photorealistic images. This study could contribute to giving guidance to produce such VR scenarios on the smartphone in the landscape study in an intuitive and brief way. Also, this study could improve the participatory planning process for more acceptable wind park landscapes, which should be further studied in future research.

The modeling of visual objects, such as roads, trees, and wind parks, could be automatized depending on their spatial distribution and the related georeferenced data. The aspects of complexity of scenarios should be further improved, as the detailed modeling by hand is time consuming. Research studies on experiencing the scenarios with the context of landscape planning in consideration of aural and visual information are mostly virtual 3D scenarios. A future study of a more convenient and cost-favorable method combining GIS data with a high level of realism can be developed.

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**Conflicts of Interest:** The authors declare no conflict of interest. The founding sponsors had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript, and in the decision to publish the results.

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# Chapter 5

# Conclusions and outlook

The focus of this thesis has been on aspects of the environmental assessment of wind parks. This final chapter summarizes the results of the PhD study and discusses the implications of the findings for researchers, landscape planners and designers. Finally, future research areas are outlined.

## 5.1 Contributions to knowledge

### 5.1.1 Demand for wind energy

The significant expansion of the global economy and technology causes a rapid rise of energy consumption. This consumption is often linked to our environment, climate and greenhouse gas emissions. Global warming has an effect of raising global average surface temperatures which could affect many species and threaten our ecosystems.

Germany is one of the largest energy markets and belongs to one of the top countries that contribute to global $CO_2$ emissions. Thus, Germany plays a significant role in influencing the global eco-environment. With the target of reducing emission by 32.3% from 2012 to 2040 on the energy consumption, Germany has been a leader in the development of renewable sources. Germany has identified wind energy as an energy development target to meet future demand and reduce greenhouse gas emissions.

The development of wind energy has thus been given a high priority, and the installations of wind turbines in Germany has reached a new high level. With 6 $GW$

capacity of installed wind power, Germany accounted for about four-fifths of total EU wind energy installations and dominated Europe installations in 2015. On the one hand, the increasing number of wind energy installations is helping meet set energy goals; on the other hand, new environmental conflicts and human conflicts are arising.

### 5.1.2 Environmental challenge for wind parks

The installation of wind turbines has been causing many problems for our planet. First of all, they are huge constructions, normally more than 100 $m$ high in the last ten years, that modify our landscape significantly. People can easily find them too visible. Today, construction has reached a height of about 150 $m$ and the installed capacity has increased to 3 $GW$ in peak electricity supply periods.

### 5.1.3 Individuals' responses toward wind parks

According to our study in Chapter 2, a comprehensive method that contains both aural and visual information on the landscape was conducted to provide a valid assessment of the impact of wind parks. This experimental study investigated the complexity of factors affecting perceptions of wind parks. Scenarios were created to evaluate a landscape without wind parks (ante operam) and the same landscape with the projected wind parks (post operam). Individuals were asked to rate their noise and visual annoyance, and the affective and cognitive impact was assessed, including tests of short-term verbal memory and executive control.

Through this study, we found that the scenarios with wind parks demonstrated a clear tendency for negative and positive values with respect to the scenarios without wind parks. However, no significant disparity was found in cognitive tests between the ante and post operam scenarios. There are no significant affective and cognitive impacts regarding the ante and post operam scenarios. This finding suggests that wind parks have little effect on psychological stress; the noise of wind turbine is thus insufficient to cause adverse health effects for human beings. The addition of auditory information could improve the visual presentations. When people experience visual displays of wind park landscapes without the sound context, the wind parks can be rated as more annoying. This study considered aural-only, visual-only, and aural-visual conditions to explore whether the wind park environment may alter the impact on annoyance toward wind parks.

It was confirmed through this experimental study that a landscape with wind parks has a negative impact on individuals' responses compared to a landscape without wind parks. The negative influences were mainly related to visual and aural annoyance, but not at an objective level in cognitive effects. This finding reveals that annoyance toward wind parks may not lead to the loss of short-term verbal memory or executive control. The perceived annoyance in different distances within 500 $m$ of the wind turbine remained the same.

Further evaluation of attitudes suggested that there was a significant correlation between attitudinal factors and subjective annoyance: the higher the negative attitude toward wind parks, the stronger the perceived annoyance. Thus, the attitude toward wind parks is a decisive factor for individuals' annoyance toward wind parks. It was interesting to find that the attitude toward the noise of the wind turbine has no significant correlation with subjective annoyance. This suggested a phenomenon that generally people have a bad impression of the noise of a wind turbine in mind, even if they do not have any real experience with wind turbines in a real landscape. In fact, the noise of wind turbines was masked by surrounding natural background sounds; thus, people do not have such strong noise annoyance as they expected.

In addition, it was found that people perceive higher noise annoyance than visual annoyance within 500 $m$ from wind turbines. The noise of wind turbines should be one of the most disturbing factors for the public compared with the visual influence. The higher the noise annoyance, the higher the visual annoyance; this result suggested that strong links exist between visual annoyance and aural annoyance. It verified the multisensory way in which humans experience wind park landscapes. The value of noise and visual annoyance were found to be correlated with the acoustical metrics. The level of sound level, loudness, fluctuation strength, and roughness were thus important factors in the evaluation of annoyance toward wind parks.

### 5.1.4 Soundscape and wind parks

Most regulations are based on noise reduction. When we design a city, a room or a rural landscape, noise would be the first aspect to be considered. However, recently, EU directives require each city in Europe to have a noise map and to quantify the quiet areas that need protection. The meaning of a quiet place and good sound quality should be scientifically defined. Therefore, lots of researchers conducted surveys to measure the sound level and interview people about sound quality (Jeon et al., 2012; Kang and Zhang, 2010). The importance of the soundscape quality is attracting more and more attention.

The term soundscape was first introduced by Schafer, a Canadian composer and environmentalist: Soundscape is a sonic environment, which is any collection of sounds, almost like a painting is a collection of visual attractions (Schafer, 1977). It is an acoustic environment, which is perceived or experienced by a person in a certain context. The soundscape study is a one-step change from noise control to soundscape design, from engineering problems to creative design issues; the difference from a traditional method is in considering environmental sounds as a resource rather than a waste (Kang, 2010). This new approach could support the design and implementation of sound environments that promote health, attract investment, convey cultural uniqueness and enhance quality of life.

As mentioned above, different acoustical metrics have significant correlation with subjective annoyance toward wind parks. The perceived aural environment was suggested as a dominant factor of individuals' interactive experiences. The acoustical environment or soundscapes of rural areas are being impacted by the increasing threat of wind turbines. With the effort to protect soundscapes and their associated values, understanding and managing soundscapes around wind parks were explored within this study. The knowledge about the effects of soundscape ambient to wind parks on people's perception based on Chapter 3 is concluded below.

In this study, an acoustic and visual preference survey was conducted to explore the effects of background sounds and non-aural factor on the perception of wind parks. Loudness was the main describing factor to explain the most variance. Noise annoyance increased with the enhancement of the sound level of ambient background sounds. Sound was proven to be significant in influencing the subjective response toward wind parks. Among them, natural sounds, especially bird sounds, could reduce perceived annoyance toward wind parks. Mechanical sounds, such as traffic sounds could increase the perceived annoyance.

In addition, the appearance of human sounds reduces the acceptance of the wind parks. For other sound sources, acceptance to wind parks remains relatively high. One of the most significant factors explaining acceptance or rejection of wind parks is human sound. In other words, visibility of wind parks should be restricted in areas with human activities.

The comparison between aural-only and aural-visual stimuli showed that the subjective ratings on the visual wind park landscapes did not differ between sites. The number of wind turbines did not show a significant effect toward subjective preference. Thus, the number of wind turbines and visual landscape may not increase individuals' annoyance with wind parks at a distance of more than 1 $km$.

Using an SD technique, the soundscapes ambient to wind parks in multidimensional scales were characterized; under an aural-visual condition, the main factors which interpret the perceived annoyance toward wind park landscapes, were "sound quality" and "relaxation". It was suggested that these two metrics are important factors associated with the perceived annoyance. Furthermore, acoustical metrics i.e. loudness, fluctuation strength, roughness and sound pressure level were found to play an important role here as well.

### 5.1.5 Realism of mobile VR simulation

In our previous research, representations of before and after views of changes in perspectives of proposed wind park landscapes were assessed with the aid of VR technology. Rapid developments of digital computer technology, interactive and 3D visualizations, could offer new opportunities to improve public communication in the planning stage. The new technology enables landscape visualization with a high level of realism, based on geodata with added detailed 3D models and dynamic processes. To further explore the realism and the relevant factors, i.e. preference ratings in the context of wind parks, the investigation of realism was carried out, and this is described in detail in Chapter 4. Within the laboratory environment, the aural-visual simulations of different real wind park landscapes were developed and rated by the individuals. The validity of these simulations of each of the investigated sites was evaluated. In addition, the aural-visual scenarios were used in the soundscape study to assess individuals' responses toward wind parks. The conclusion regarding these research questions is summarized below.

With the aid of the Unity 3D program, simulated aural-visual virtual scenarios of wind parks were developed for assessing their impact on perceived landscape quality in communication processes. The produced aural-visual simulations with the dynamic process were proved successfully for 3D virtual scenarios of wind parks with relatively high level of realism. The scenarios link acoustic information into the simulated models. Representation of landscape scenarios should take sound information into account to enhance its realism. It was further found that the improvement of "diversity" of the soundscape for the wind park scenarios could increase perceived realism. In addition, the visual information shall be identified with the sound information presented in the surveyed scenarios. Good light, color and vegetation of the scenarios are further important factors to ensure a good quality of realism.

With the research on this method, we contribute to giving guidance to produce such aural-visual scenarios for the landscape study in an intuitive and brief way. Overall, this method, with the addition of spatial sound information, could contribute significantly in enhancing environmental assessments of wind park landscapes and thus allow more comprehensible and scientific decisions than conventional tools, i.e. GIS maps and photo-realistic images.

## 5.2 Outlook to future research

This dissertation presents new approaches for the assessment of wind parks and explores the factors affecting the human responses toward wind parks. In this research project, the aural-visual stimuli in VR simulation of the experimental environment were applied. Ambient environmental noise was added, i.e. man-made sounds including traffic sounds and human sounds, and sounds from the natural environment including bird sounds, wind and stream sounds. The masking effects and the interaction of aural-visual information were investigated. The findings could offer scientifically-based suggestions for landscape planners and local stakeholders with respect to wind park projects. The results may not be specific to Germany or for other countries, as this was not the purpose of the study. Rather, the present study provides a more comprehensive perspective on the design and planning of landscape for wind parks at a local scale. The study could improve participatory planning processes for more acceptable wind park landscapes, which should be further studied in future research.

This PhD research project provided an exploratory analysis of the effect of aural-visual characteristics on subjective and objective responses toward wind park landscapes. The findings identify clear impacts on annoyance. The attitude toward wind turbines was shown to be significantly linked with the subjective ratings. In consideration of the consistency of the data acquired, the investigated group in our study are mostly young students or staff from the University of Rostock with the age range of 18 to 35-years-old. The characteristics of the participants could influence strongly the responses to wind parks. Based on our study, researchers can take this point into consideration for future data collection. Further assessment experiments on subject groups of the stakeholders and the residents near wind parks need to be conducted. The findings of our study need to be verified and any important characteristics of participants (i.e. the professional background, familiarity with wind turbines, gender etc.) other than ours should be identified.

Since 2009, the amount of research on the soundscape has been growing steadily. Soundscape research is receiving increasing attention from all fields by researchers, policymakers and practitioners. However, it is still an evolving, interdisciplinary science and there is a lack of proposed models that identify the underlying dimensions of soundscape assessment that may guide investigations and responses in the context of wind parks, for landscape researchers (Axelsson et al., 2010). Reducing noise level did not likely to enhance the quality in our landscape; this is also a reason for conducting soundscape approach to study people's real preference for landscapes with the purpose of improving quality of life (Kang et al., 2016). The standard for the soundscape definitions and framework has been provided by International Organization for Standardization (ISO12913-1, 2014), though the systematic methods in soundscape data collection in an ecologically valid way are still needed.

This PhD thesis has the potential to explain the meaning and improve understanding between different groups involved in decision-making in the design and planning of landscape. The PhD study presented here has raised important research questions particularly of concerning soundscape characteristics and subjective and objective responses in the context of wind parks, for landscape researchers. While further research is needed in this area, our investigations have provided a preliminary framework and empirical evidence, based on which further study on important aspects relating to landscape study could be extended.

In our study, perceived realism was explored, which could be used for comparison with other landscape studies based on aural-visual interaction information. The aural-visual simulation tool was developed and tested in the study research. For the visual simulation, the generation of the land-use texture or the placement of the models, i.e. vegetation, trees and roads etc., could be automated depending on their spatial distribution and the related geodata references. The aspects of the complexity of scenarios should be further improved. A walk-through technique could be combined with this study in future research in order to reduce differences between the animated and the real world. Research on experiencing the scenarios in the context of landscape planning using aural and visual information is mostly carried out using virtual 3D scenarios. A more convenient and cost-favorable method combining GIS data with a high-level of realism can be developed in future research.

For the aural simulation, on-site sound recordings were conducted, and the acoustical information in the simulation was mainly formed from field measurements. The ambient sounds of wind parks were included in our study; however, sounds from different wind turbines types were not considered. The auralization of different wind turbine types could be integrated in future research study. Moreover, real-time generation of acoustical information in consideration of user interaction could be considered, including altering parameters of receiver positions and positions of sound sources. The technical aspects required to achieve this study point are accessible, through the combination of multi-disciplinary subjects i.e. advanced programming knowledge is needed.

In our study, representations in a VR environment of real wind park landscapes were made in an experimental laboratory. However, an on-site situation is also very important for user experience and landscape assessment. The on-site investigation with proposed wind park projects could enable a real site experience. Investigations could be conducted on-site while people are observing and hearing in the survey site with the aid of visual and acoustic information of the proposed wind park. The application of augmented reality (AR) technology may contribute to this research field and enhance the understanding of landscape changes. Overall, in landscape research study, the new technologies should be considered to provide methodologies that are more comprehensive and to acquire more valid data for scientific suggestions.

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# List of Figures

# List of Tables

# List of Abbreviations

| | |
|---|---|
| **ANOVA** | **AN**alysis **O**f **VA**riances |
| **AR** | **A**ugmented **R**eality |
| **BauGB** | **B**au**G**esetz**B**uch |
| **BDS** | **B**ackward **D**igit **S**pan |
| **BImSchG** | **B**undest-**Im**missions**Sch**utz**G**esetz |
| **BNatSchG** | **B**undes**N**atur**Sch**utz**Gesetz** |
| **Btu** | **B**ritish **t**hermal **u**nits |
| **dBA** | **A**-weighted **d**eci**B**els |
| **DEM** | **D**igital **E**levation **M**odel |
| **EEG** | **E**rneuerbare-**E**nergien-**G**esetz |
| **EMI** | **E**lectromagnetic **I**nterference |
| **GDI** | **G**eo**D**ata**I**nfrastructure |
| **GIS** | **G**eographical **I**nformation **S**ystem |
| **GW** | **G**iga **W**att |
| **IEA** | **I**nternational **E**nergy **A**gency |
| **KMO** | **K**aiser-**M**eyer-**O**lkin |
| **LPlG** | **L**andes**Pl**aungs**G**esetz |
| **M-V** | **M**ecklenburg-**V**orpommern |
| **MW** | **M**ega **W**att |
| **NIMBY** | **N**ot **I**n **M**y **B**ack**Y**ard |
| **OSHA** | **O**ccupational **S**afety & **H**ealth **A**dministration Standards |
| **PANAS** | **P**ostive and **N**egative **A**ffect **S**chedule |
| **PCA** | **P**rincipal **C**omponent **A**nalysis |
| **ROG** | **R**aum**O**rdnungs**G**esetz |
| **SD** | **S**emantic **D**ifferential technique |
| **S.D.** | **S**tandard **D**eviation |
| **UVPG** | Gesetz über die **U**mwelt**V**erträglichkeits**P**rüfung |
| **VEZ** | **V**isual **E**xposure **Z**ones |
| **VR** | **V**irtuale **R**eality |
| **ZTV** | **Z**ones of **T**heoretical **V**isibility |
| **ZVI** | **Z**ones of **V**isual **I**nfluence |

***Questionnaire: Preference of a new wind park project***
***The university of Rostock***
LANDSCAPE PLANNING AND LANDSCAPE DESIGN

**Place:**
**Date:** **.2015**
**No.:**

**PERSONAL DETAILS**

| | |
|---|---|
| Name: | Age: |
| Gender: ☐male/ ☐ female | Usual residence City/Country: |

**PANAS Questionnaire**

This scale consists of a number of words that describe different feelings and emotions. Read each item and then list the number from the scale below next to each word**. Indicate to what extent you feel this way right now, that is, at the present moment (circle the instructions you followed when taking this measure)**

| | 1. Not at all | 2. A little | 3. Modera tely | 4. Definite ly | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

i

***Questionnaire: Preference of a new wind park project***
***The university of Rostock***
LANDSCAPE PLANNING AND LANDSCAPE DESIGN

It involves interviewers slowly reading out successively longer strings of single-digit numbers and asking participants to repeat those strings in reverse order. Respondents are given two chances at each length or level. When the respondent gets one trial correct at a level, the first trial at the next level is administered. If the first trial is incorrect, the second trial is administered. **If both responses at the same level are incorrect, the test is discontinued. The shortest sequence administered is two digits and longest one is eight digits.**

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Very negative | | | | | | | | | | very positive |
|---|---|---|---|---|---|---|---|---|---|---|---|
| What is your attitude towards a new wind turbines? | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| What is your attitude towards the integration of the wind farm with the landscape? | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| What is your attitude toward the sound of wind turbines? | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| What is your attitude towards more wind turbines? | **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |

ii

## ***Questionnaire: Preference of a new wind park project***

**Please watch the short videos/sounds, answer the following questions:**

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ... Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |

| | Very negative ... very positive |
|---|---|
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 1

## Questionnaire: Preference of a new wind park project

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ... Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ... very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 2

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all — Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative — very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 3

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ← → Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ← → very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 4

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ← → Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ← → very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 5

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Modera tely | 4. Definite ly | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ... Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ... very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 6

## Questionnaire: Preference of a new wind park project

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ← → Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ← → very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 1

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all … Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative … very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 2

## Questionnaire: Preference of a new wind park project

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ... Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |

| | Very negative ... very positive |
|---|---|
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 3

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all … Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative … very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 4

## Questionnaire: Preference of a new wind park project

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ← → Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ← → very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 5

## Questionnaire: Preference of a new wind park project

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all — Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative — very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 6

## Questionnaire: Preference of a new wind park project

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all … Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative … very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 7

## ***Questionnaire: Preference of a new wind park project***

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ... Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ... very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 8

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ← → Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ← → very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 9

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all — Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative — very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 10

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ← → Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ← → very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 11

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ... Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ... very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 12

## Questionnaire: Preference of a new wind park project

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ... Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ... very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 13

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all — Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative — very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 14

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ← → Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |

| | Very negative ← → very positive |
|---|---|
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 15

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ← → Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ← → very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 16

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ← → Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ← → very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 17

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ← → Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ← → very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 18

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ... Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ... very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 19

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ... Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |

| | Very negative ... very positive |
|---|---|
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 20

## *Questionnaire: Preference of a new wind park project*

**PANAS Questionnaire**

Rate how you are feeling right now.

| | 1. Not at all | 2. A little | 3. Moderately | 4. Definitely | 5.Very much |
|---|---|---|---|---|---|
| 1. Interested/ Interessiert | | | | | |
| 2. Distressed/ bekümmert | | | | | |
| 3. Excited/ freudig erregt | | | | | |
| 4. Upset/ verärgert | | | | | |
| 5. Strong/ stark | | | | | |
| 6. Guilty /schuldig | | | | | |
| 7. Scared/ erschrocken | | | | | |
| 8. Hostile/ feindlich | | | | | |
| 9. Enthusiastic /begeistert | | | | | |
| 10. Proud/ stolz | | | | | |
| 11. Irritable/ reizbar | | | | | |
| 12. Alert /Wach | | | | | |
| 13. Ashamed /beschämt | | | | | |
| 14.Inspired/ angeregt | | | | | |
| 15.Nervous/ Nervös | | | | | |
| 16.Determined/ entschlossen | | | | | |
| 17.Attentive/ aufmerksam | | | | | |
| 18.Jittery /Durcheinander | | | | | |
| 19.Active/ Aktiv | | | | | |
| 20.Afraid/ Ängstlich | | | | | |

**Backward digit span BDS**

Repeat the number that you heard.

| | |
|---|---|
| **5** | |
| **6** | |
| **7** | |
| **8** | |

**QUESTIONS**

**Please circle the number of your choice according to each questions.**

| | Not at all ... Very much |
|---|---|
| How much did the visual aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| How much did the auditory aspects of the scenario annoy you? | **0 1 2 3 4 5 6 7 8 9 10** |
| | Very negative ... very positive |
| How would you rate this scenario? | **0 1 2 3 4 5 6 7 8 9 10** |

Test Nr. 21

Wind park soundscapes - sound level investigation

| Place: (Site); (Coordinate data). Time: (hh/mm)<br>Environment condition: Name: | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| 9 | | | | | | | | | | |
| 10 | | | | | | | | | | |

| Place: Time: (hh/mm)<br>Environment condition: Name: | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| 1 | | | | | | | | | | |
| 2 | | | | | | | | | | |
| 3 | | | | | | | | | | |
| 4 | | | | | | | | | | |
| 5 | | | | | | | | | | |
| 6 | | | | | | | | | | |
| 7 | | | | | | | | | | |
| 8 | | | | | | | | | | |
| 9 | | | | | | | | | | |
| 10 | | | | | | | | | | |

| EvaSys | Wahrnehmung von Windparks unter visuell-akustischer Simulation-without schatten | Electric Paper |
|---|---|---|

Bitte so markieren: ☐ ☒ ☐ ☐ ☐ Bitte verwenden Sie einen Kugelschreiber oder nicht zu starken Filzstift. Dieser Fragebogen wird maschinell erfasst.

Korrektur: ☐ ■ ☐ ☒ ☐ Bitte beachten Sie im Interesse einer optimalen Datenerfassung die links gegebenen Hinweise beim Ausfüllen.

## 1. Allgemeine Frage

1.1 Sie sind... ☐ weiblich ☐ männlich

1.2 Bitte geben Sie Ihr Alter an:

| | x0 | x1 | x2 | x3 | x4 | x5 | x6 | x7 | x8 | x9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 10er | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |
| 1er | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ |

1.3 Wie sehen Sie Windenergie? ☐ sinnvoll ☐ sinnlos ☐ meinungslos

1.4 Bisherige Erfahrung mit Windkraftanlagen? ☐ positiv ☐ negativ ☐ k.A.

**Fragen zur Simulation**

1.5 Wie empfinden Sie die akustischer Reize? gar nicht störend ☐ ☐ ☐ ☐ ☐ ☐ ☐ sehr störend

**Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 1.6 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 1.7 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 1.8 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 1.9 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 1.10 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |
| 1.11 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 1.12 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 1.13 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 1.14 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 1.15 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

## 2. Frage zur Simulation

2.1 Wie empfinden Sie die akustischer Reize? gar nicht störend ☐ ☐ ☐ ☐ ☐ ☐ ☐ sehr störend

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 2.2 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 2.3 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 2.4 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 2.5 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 2.6 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |
| 2.7 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 2.8 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 2.9 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 2.10 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 2.11 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

## 3. Frage zur Simulation

3.1 Wie empfinden Sie die akustischer Reize? gar nicht störend ☐ ☐ ☐ ☐ ☐ ☐ ☐ sehr störend

**Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3.2 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |

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| EvaSys | Wahrnehmung von Windparks unter visuell-akustischer Simulation-without schatten | Electric Paper |
|---|---|---|

## 3. Frage zur Simulation [Fortsetzung]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3.3 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 3.4 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 3.5 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 3.6 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |
| 3.7 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 3.8 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 3.9 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 3.10 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 3.11 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

## 4. Frage zur Simulation

4.1 Wie empfinden Sie die akustischer Reize? gar nicht störend ☐ ☐ ☐ ☐ ☐ ☐ ☐ sehr störend

**Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)**

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 4.2 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 4.3 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 4.4 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 4.5 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 4.6 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |
| 4.7 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 4.8 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 4.9 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 4.10 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 4.11 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

## 5. Frage zur Simulation

5.1 Wie empfinden Sie die akustischer Reize? gar nicht störend ☐ ☐ ☐ ☐ ☐ ☐ ☐ sehr störend

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5.2 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 5.3 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 5.4 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 5.5 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 5.6 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |
| 5.7 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 5.8 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 5.9 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 5.10 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 5.11 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

## 6. Frage zur Simulation

6.1 Wie empfinden Sie die akustischer Reize? gar nicht störend ☐ ☐ ☐ ☐ ☐ ☐ ☐ sehr störend

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6.2 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 6.3 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 6.4 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 6.5 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 6.6 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |

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|---|---|---|

## 6. Frage zur Simulation [Fortsetzung]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6.7 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 6.8 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 6.9 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 6.10 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 6.11 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

## 7. Frage zur Simulation

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 7.1 Wie empfinden Sie die akustischer Reize? | gar nicht störend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr störend |

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 7.2 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 7.3 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 7.4 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 7.5 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 7.6 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |
| 7.7 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 7.8 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 7.9 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 7.10 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 7.11 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

## 8. Frage zur Simulation

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 8.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr gut |
| 8.2 Wie empfinden Sie die visueller Reize? | gar nicht störend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr störend |
| 8.3 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 8.4 Wie realistisch empfinden Sie die Beleuchtung in der Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 8.5 Wie realistisch empfinden Sie die Farbe? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 8.6 Wie realistisch empfinden Sie die Vegetation/Bäume/ Sträucher? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |

## 9. Frage zur Simulation

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 9.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr gut |
| 9.2 Wie empfinden Sie die visueller Reize? | gar nicht störend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr störend |
| 9.3 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 9.4 Wie realistisch empfinden Sie die Beleuchtung in der Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 9.5 Wie realistisch empfinden Sie die Farbe? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 9.6 Wie realistisch empfinden Sie die Vegetation/Bäume/ Sträucher? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |

## 10. Frage zur Simulation

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|---|---|---|

## 10. Frage zur Simulation [Fortsetzung]

| | | | |
|---|---|---|---|
| 10.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr gut |
| 10.2 Wie empfinden Sie die visueller Reize? | gar nicht störend | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr störend |
| 10.3 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 10.4 Wie realistisch empfinden Sie die Beleuchtung in der Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 10.5 Wie realistisch empfinden Sie die Farbe? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 10.6 Wie realistisch empfinden Sie die Vegetation/Bäume/ Sträucher? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |

## 11. Frage zur Simulation

| | | | |
|---|---|---|---|
| 11.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr gut |
| 11.2 Wie empfinden Sie die visueller Reize? | gar nicht störend | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr störend |
| 11.3 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 11.4 Wie realistisch empfinden Sie die Beleuchtung in der Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 11.5 Wie realistisch empfinden Sie die Farbe? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 11.6 Wie realistisch empfinden Sie die Vegetation/Bäume/ Sträucher? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |

## 12. Frage zur Simulation

| | | | |
|---|---|---|---|
| 12.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr gut |
| 12.2 Wie empfinden Sie die visueller Reize? | gar nicht störend | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr störend |
| 12.3 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 12.4 Wie realistisch empfinden Sie die Beleuchtung in der Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 12.5 Wie realistisch empfinden Sie die Farbe? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 12.6 Wie realistisch empfinden Sie die Vegetation/Bäume/ Sträucher? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |

## 13. Frage zur Simulation

| | | | |
|---|---|---|---|
| 13.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr gut |
| 13.2 Wie empfinden Sie die visueller Reize? | gar nicht störend | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr störend |
| 13.3 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 13.4 Wie realistisch empfinden Sie die Beleuchtung in der Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 13.5 Wie realistisch empfinden Sie die Farbe? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |

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|---|---|---|

## 13. Frage zur Simulation [Fortsetzung]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 13.6 Wie realistisch empfinden Sie die Vegetation/Bäume/ Sträucher? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |

## 14. Frage zur Simulation

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 14.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr gut |
| 14.2 Wie empfinden Sie die visueller Reize? | gar nicht störend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr störend |
| 14.3 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 14.4 Wie realistisch empfinden Sie die Beleuchtung in der Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 14.5 Wie realistisch empfinden Sie die Farbe? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 14.6 Wie realistisch empfinden Sie die Vegetation/Bäume/ Sträucher? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |

## 15. Frage zur Simulation

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr gut |
| 15.2 Wie stark fühlen Sie sich gestört durch der visuell-akustischer Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 15.3 Wie empfinden Sie die akustischer Reize? | gar nicht störend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr störend |
| 15.4 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15.5 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 15.6 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 15.7 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 15.8 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 15.9 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |
| 15.10 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 15.11 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 15.12 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 15.13 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 15.14 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

## 16. Frage zur Simulation

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 16.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr gut |
| 16.2 Wie stark fühlen Sie sich gestört durch der visuell-akustischer Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 16.3 Wie empfinden Sie die akustischer Reize? | gar nicht störend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr störend |
| 16.4 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 16.5 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 16.6 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 16.7 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 16.8 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 16.9 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |

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| EvaSys | Wahrnehmung von Windparks unter visuell-akustischer Simulation-without schatten | Electric Paper EVALUATIONSSYSTEME |
|---|---|---|

## 16. Frage zur Simulation [Fortsetzung]

| | | | |
|---|---|---|---|
| 16.10 | offen | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | geschlossen |
| 16.11 | beruhigend | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | nervös |
| 16.12 | natürlich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | künstlich |
| 16.13 | ordentlich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | unordentlich |
| 16.14 | weich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | hart |

## 17. Frage zur Simulation

| | | | |
|---|---|---|---|
| 17.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr gut |
| 17.2 Wie stark fühlen Sie sich gestört durch der visuell-akustischer Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 17.3 Wie empfinden Sie die akustischer Reize? | gar nicht störend | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr störend |
| 17.4 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | |
|---|---|---|---|
| 17.5 | angenehm | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | unangenehm |
| 17.6 | vielseitig | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | eintönig |
| 17.7 | leise | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | laut |
| 17.8 | glatt | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | rauh |
| 17.9 | gemütlich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | ungemütlich |
| 17.10 | offen | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | geschlossen |
| 17.11 | beruhigend | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | nervös |
| 17.12 | natürlich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | künstlich |
| 17.13 | ordentlich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | unordentlich |
| 17.14 | weich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | hart |

## 18. Frage zur Simulation

| | | | |
|---|---|---|---|
| 18.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr gut |
| 18.2 Wie stark fühlen Sie sich gestört durch der visuell-akustischer Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |
| 18.3 Wie empfinden Sie die akustischer Reize? | gar nicht störend | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr störend |
| 18.4 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | extrem |

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | |
|---|---|---|---|
| 18.5 | angenehm | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | unangenehm |
| 18.6 | vielseitig | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | eintönig |
| 18.7 | leise | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | laut |
| 18.8 | glatt | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | rauh |
| 18.9 | gemütlich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | ungemütlich |
| 18.10 | offen | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | geschlossen |
| 18.11 | beruhigend | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | nervös |
| 18.12 | natürlich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | künstlich |
| 18.13 | ordentlich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | unordentlich |
| 18.14 | weich | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | hart |

## 19. Frage zur Simulation

| | | | |
|---|---|---|---|
| 19.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ ☐ ☐ ☐ ☐ ☐ ☐ | sehr gut |

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|---|---|---|

## 19. Frage zur Simulation [Fortsetzung]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 19.2 Wie stark fühlen Sie sich gestört durch der visuell-akustischer Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 19.3 Wie empfinden Sie die akustischer Reize? | gar nicht störend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr störend |
| 19.4 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 19.5 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 19.6 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 19.7 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 19.8 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 19.9 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |
| 19.10 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 19.11 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 19.12 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 19.13 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 19.14 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

## 20. Frage zur Simulation

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 20.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr gut |
| 20.2 Wie stark fühlen Sie sich gestört durch der visuell-akustischer Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 20.3 Wie empfinden Sie die akustischer Reize? | gar nicht störend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr störend |
| 20.4 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 20.5 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 20.6 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 20.7 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |
| 20.8 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 20.9 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |
| 20.10 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 20.11 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 20.12 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 20.13 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 20.14 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

## 21. Frage zur Simulation

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 21.1 Wie sehen Sie die Integration der Windenergieanlage in der Simulation? | sehr schlecht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr gut |
| 21.2 Wie stark fühlen Sie sich gestört durch der visuell-akustischer Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |
| 21.3 Wie empfinden Sie die akustischer Reize? | gar nicht störend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | sehr störend |
| 21.4 Wie realistisch empfinden Sie die Simulation? | gar nicht | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | extrem |

***Wie beurteilen Sie die akustischer Reize? (Semantisches Differential Test)***

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 21.5 | angenehm | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unangenehm |
| 21.6 | vielseitig | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | eintönig |
| 21.7 | leise | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | laut |

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| EvaSys | Wahrnehmung von Windparks unter visuell-akustischer Simulation-without schatten | Electric Paper |
|---|---|---|

## 21. Frage zur Simulation [Fortsetzung]

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 21.8 | glatt | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | rauh |
| 21.9 | gemütlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ungemütlich |
| 21.10 | offen | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | geschlossen |
| 21.11 | beruhigend | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | nervös |
| 21.12 | natürlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | künstlich |
| 21.13 | ordentlich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | unordentlich |
| 21.14 | weich | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | ☐ | hart |

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# Curriculum Vitae

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## Research area

**Landscape planning and geoinformatik, Soundscape, Environmental assessment**

## Education

| | |
|---|---|
| 2014.10-TO DATE | **Rostock University**, Rostock, Germany<br>Pursuing Ph.D in Landscape Planning/Geoinformatik. |
| 2010.10-2012.12 | **Rostock University**, Rostock, Germany<br>M.Sc. in Land Cultivation and Environmental Protection. |
| 2006.09-2010.06 | **Hefei University**, Hefei, China<br>B.Sc. in Environmental Engineering. |

## List of publications

| | |
|---|---|
| MAR. 2018 | **Validity of VR technology on the smartphone for the study of wind park soundscapes,**<br>**Tianhong Yu**, Holger Behm, Ralf Bill, Jian Kang: ISPRS International Journal of Geo-Information, 7, 152, 2018<br>http://dx.doi.org/10.3390/ijgi7040152 |
| NOV. 2017 | **Factors associated with soundscape experiences in urban green spaces: A case study in Rostock, Germany**<br>Liu, J., Wang, Y., Zimmer, C., Kang, J., **Yu, T.**: Urban Forestry and Urban Greening<br>https://doi.org/10.1016/j.ufug.2017.11.003 |
| SEP. 2017 | **Audio-visual perception of new wind parks** |

Tianhong Yu, Holger Behm, Ralf Bill, Jian Kang: Landscape and Urban Planning, Vol. 165, pp. 1-10.
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JAN. 2018 **Assessment of soundscape ambient wind parks**
**Tianhong Yu**, Holger Behm, Ralf Bill, Jian Kang: Landscape and Urban Planning, Under review

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AUG. 2017 **Effects of soundscape on preferences of the setting of wind parks with an audio-visual approach**
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Tianhong Yu, Holger Behm. In: Posters. CHeriScape: Landscape in imagination and the virtual future. Conference V, Newcastle, 14-16 June 2016.

SEPT. 2015 **Energy landscapes in Europe the view from China**
Tianhong Yu, Holger Behm. In: Book of Abstracts. Energy Landscapes: Perception, Planning, Participation and Power. European Conference of the Landscape Research Group, Dresden, 16-18 September 2015., p.7.