Noise Reduction Measures of Noisy Kitchen Devices and Evidence of their Improvement by an Objective Analysis of Spontaneous EEG Measurements

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ABSTRACT

In modern life, influence of noise becomes more and more important. Especially at home, Europeans desire a quieter kitchen. In general small, electromotive-driven appliances and in particular blenders can generate inconvenient home noise emission. Noise excitations of these devices were diagnosed experimentally. On this, constructions were applied to modify noise emission. The modified noise emissions were compared in terms of sound power level and psychoacoustic parameters like loudness, sharpness and roughness. In order to analyze objectively the psycho-physiological stress caused by these noises, a spontaneous EEG experiment was conducted. “Original noise” of the device and modified “optimized noises” were taken as experimental stimuli. Impact of the noises on psycho-physiological stress of experimental subjects (n = 20) were measured by spontaneous EEG. Through power density distribution, evidence on significant differences between “original noise” and “optimized noises” were found. The power density distributions of the “optimized noises” as compared to the “original noise” come closer to the distribution when subjects are relaxed-awake. This showed that the modifications have been successful as measured through an objective mean.

Keywords: Kitchen Noise, Sound Quality, Noise Perception I-INCE Classification of Subjects Number(s): 12.4.5

1. INTRODUCTION

With increasing life quality, noise emission in society becomes more and more important. Noise emission will increase in daily life and will be less and less accepted. This is because increased exposure to noise emission induced disturbances, hearing impairment, sleep disturbance and cardio-vascular problems (1). Cardio-vascular diseases are the most common cause of death in Germany (2). Hearing damage was over a long time the most accepted industrial disease in Germany (3). Currently, nearly 15 million people in Germany have hearing impairment and/or tinnitus. Hearing impairment is intensified in young people (4).

Laws, regulations and standards exist for diverse kinds of noises, on special places and at certain times. For example, the upper tripping threshold is limited to 85 dB(A) during exposure time of 8 hours at work. However, noise disturbance during free time is also relevant. For a time period of 10 hours after work, sound pressure level lower than 70 dB(A) is recommended to prevent hearing impairment (5). Besides hearing impairment, noise pollution leads to vegetative nervous system of humans already by 65 - 75 dB(A). Psychological responses should be expected by 30 - 40 dB(A) (6). This low tripping threshold shows that noise outside working time is important. In leisure time, traffic noise, followed by air and by railway traffic, produce main stresses (7). Also noise emission in private household is highly undesired. In general, kitchen represents the noisiest room at home and 40 % of Europeans wish a quieter kitchen (8). Furthermore, kitchen is in general the room with lowest sound absorbing materials like curtains or carpets. Major noise sources come from small,

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electromotive-driven kitchen devices (9). These devices can be found more and more in general kitchens.

2. METHODOLOGY

Noisy kitchen devices were detected via preliminary investigation. Noise reduction measures e.g. encapsulation, damping and decoupling were realized to highly noisy kitchen devices. Sounds during each modification steps were recorded. Psychoacoustic parameters were determined for “original noise” and “optimized noises”. Impact and optimization of kitchen devices were analyzed by spontaneous EEG-measurements (n = 20) (10). During spontaneous EEG treatment, activation level was observed. In main focus were alpha waves. These alpha waves showed high power density distribution at cortex parietal and occipital, if the participants have closed eyes and were in relaxed condition (11-12). Power density distribution will show modification as a consequence of a changed psycho-physiological stress. This characteristic was investigated to verify different noises of the kitchen device. This means, that the study showed methods on how constructive modifications could influence noise emission of small, electromotive driven kitchen devices. Differences of psycho-physiological sound perception can be objectively analyzed with spontaneous EEG measurement.

3. PRELIMINARY INVESTIGATIONS

There are a lot of noisy kitchen devices in every kitchen. Table 1 gives an overview of different electromotive driven kitchen devices. These devices were investigated in former studies (9). A-weighted sound pressure levels present noise pollution for users during use of these devices. Variety of A-weighted sound pressure levels depends on type, producer, operation point and (if there is on) filling medium.

Table 1 – A-weighted sound pressure level of kitchen devices (9)

Device	Distance in m	L_{pA} in dB(A)
blenders	0.6	82 - 91
hand mixers	0.6	77 - 86
electrical coffee grinders	0.6	71 - 83
electrical grain mills	0.6	75 - 79
espresso machines	0.6	61 - 71
extractors	0.4	54 - 68

Due to it being the noisiest device, blenders were used for the investigations. Noise emission of blenders depends on operation points, product quality and electric power consumption. Table 2 shows noise emission of different blender types. Especially noisy was a cheap blender with average electric power consumption. This type of blender was used for further investigations.

Table 2 – A-weighted sound pressure level of different blenders (9)

Product	L_{pA} in dB(A)	Electrical power consumption in W	Price in €
Elta MX 100N	83	350	“27”
Team International T610	82	400	“25”
Clatronic	89	450	“25”
Severin SM 3714	91	600	“30”
Krups Power XL6	85	600	“79”
Philips HR2094	83	750	“100”

4. NOISE EMISSION

4.1 Starting Conditions

In general, blenders consist of a stand with electric (usually series-wound) motor and a measuring vessel with blade unit. Power transmission of the electric motor to the blade unit is managed by a flexible coupling. Through coupling geometry, some different coupling opportunities between the electric motor and the blade unit exist. Noise emission of blenders essentially depends on operation points and used materials. Noise emission increases with rotation speed of the electric motor. Through a growing filling level of the measuring vessel with a constant medium, the rotation speed and consequently the noise emission is decreased accordingly. Consequently, combination of coupling between electric motor and blade unit influences noise excitation of the investigated blender. In this case noise levels differ up to 3 dB. Imbalance and deflection of rotating components increase noise excitation. Comparison between three blenders of the chosen type results in total sound power level (SPL) between 82 to 87 dB(A). SPL was determined by (13). These blenders were run in disadvantageous coupling combination during different operating conditions. The measuring vessel was filled with water to generate stationary operating conditions. Nevertheless transient levels differ up to ±2 dB. This variation is based on flow processes of the measurement filling.

4.2 Sources of Noise

Sources of noise of the investigated blender are coming from broadband stimuli and especially by tonal components of electric motor. Tonal components were traced back to rotary frequency and their harmonics that were generated by imbalance. An unequal mass distribution and deflections of rotating components created the imbalance forces. These forces essentially increase noise excitation.

Another source of noise is bearing. This source of noise can be influenced through lubrication. After a long term use, the lubricant in (plain) bearings is reduced. This means that broadband (stochastic) spectra which then appear will generate noise stimulus.

Additional sources of noise are flow disturbances in the cooling air especially by fan in electric motor as well as by blade unit and by movement of fluid in measuring vessel. According to (14), the magnetic noise excitations are not relevant in this type of engine.

4.3 Reduction of Noise

Noise emissions of machines can be modified through direct or indirect arrangements. Noise reduction arrangements such as full encapsulation, damping and decoupling were utilized and significant SPL reduction was achieved. Table 3 shows several reduction arrangements relative to starting conditions of the three blenders.

Table 3 – Properties of noise modifications investigations and A-weighted sound pressure level differences by variety of reduction arrangements

Variation	Starting condition	Damping	Encapsulation	Decoupling	Advantageous coupling combination	Disadvantageous coupling combination	Difference of SPL
A	X					X	---
B	X				X		-2
C		X			X		-5
D		X	X		X		-9
E		X	X	X	X		-12

In particular, damping is an effective mean to reduce noise emission. In this case, the blender was dampened by bitumen pad (empty weight increases from 2.3 kg up to 3.1 kg). Noise emission up to 3 dB is reduced in this case. Figure 1 shows broadband sound pressure level reductions of this arrangement for one of the investigated blenders.

Additionally, a noise reduction was realized through the use of a special absorber between blender and ground unit. In this case, decoupling to ground as well as sound absorption of air cooling resulted in a reduction of noise. SPL is reduced up to 4 dB in relation to the "damping" blender. This modification was hence called 'decoupling', see Figure 1. A full encapsulation was realized by a sheet metal housing with a sound absorber (thickness: 30 mm) on its inside. A significant noise reduction in relation to the 'decoupling' blender was achieved in frequency range above 800 Hz, see also figure 1.

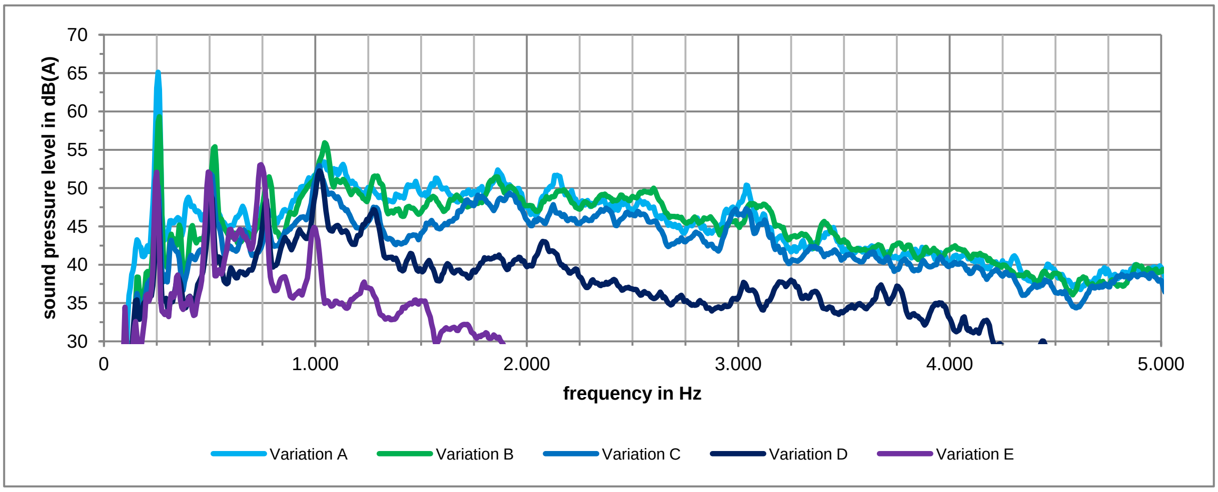

Figure 1 – Influence of damping, decoupling and encapsulation to sound pressure level of an investigated blender during maximum rotation speed and half-filled measuring vessel, measurements according to (13)

Further modifications like optimization of air flow, optimization of bearing lubrication and increase of moments of inertia were realized. The reduction of SPL was smaller compare to former explained optimizations (damping, encapsulation, decoupling). For this reason, the results were not investigated further.

Besides SPL modifications, sound quality was changed in a significant way. Some psychoacoustic parameters are represented in table 4. Variations of changes are based on variation A. In particular, sharpness and tonality are significantly different. These influences were observed through the use of absorber and damp material.

Table 4 – Psychoacoustic parameters of noise modifications

Variation	Loudness	Sharpness	Tonality	Roughness	Fluctuation strength
A	---	---	---	---	---
B	↓	---	---	↓	↓
C	↓↓	---	↓	↓	↓
D	↓↓↓	↓	---	↓↓	↓
E	↓↓↓↓	↓↓	↑	↓↓↓	↓

4.4 Noise Matrix

Three different noises were chosen to test the influence of noise optimizations on psycho-physiological stress. Several silence phases were introduced, see table 5. Variation A refers to the “original noise” of the investigated device. Variation C and Variation D are various optimized noises. During all phases, spontaneous EEG was measured.

Table 5 – Noise matrix with selected noises

Description	Duration	Time slot
Silence 1	1 minute	0 – 1 minute
Variation A	2 minutes	1 – 3 minute
Variation C	2 minutes	3 – 5 minute
Variation D	2 minutes	5 – 7 minute
Silence 2	1 minute	7 – 8 minute
Variation A	2 minutes	8 – 10 minute
Variation C	2 minutes	10 – 12 minute
Variation D	2 minutes	12 – 14 minute
Silence 3	1 minute	14 – 15 minute

5. EXPERIMENTAL SUBJECT

For experimental investigations, 20 male, right handed, good hearing participants within the age of 21 - 27 years were selected. Comparability of participants was very important for the upcoming investigation. Good hearing condition of participants was confirmed with an audiometer at the beginning of the investigations. The maximum acceptable permanent threshold shift was fixed at 15 dB. Furthermore a questionnaire was administrated, to guarantee comparability of health status (e.g. use of drugs, tinnitus). Right handed and male participants were selected, to exclude differences between handedness and gender parameters. Additionally, selected participants were not workers for kitchen appliances producers or in a business related to the investigated topic.

6. INFLUENCE OF NOISE ON PSYCHO-PHYSIOLOGICAL STRESS

6.1 Measurement Method

Influence of noise on psycho-physiological stress was measured through spontaneous EEG. Thirty-one electrodes were used for spontaneous EEG modeled after ten-twenty-system (15). The measurements took place in a laboratory with little or no background noise. Recorded differences in potential fluctuations of single electrode (see figure 2) were linked by reference principle.

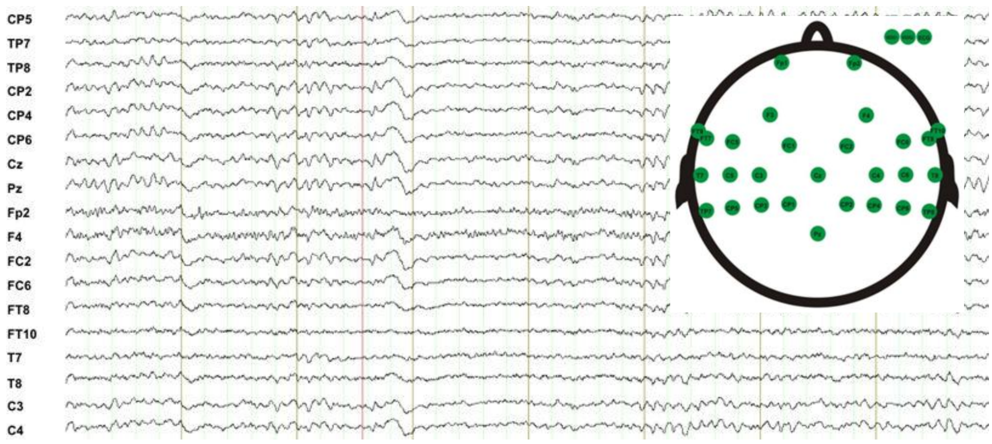

Figure 2 – Potential differences (Y-axis) over time (X-axis) of single electrode (extraction) and location at cortex of spontaneous EEG measurement (15)

Derived potential fluctuations at cortex were analyzed and provided references for its frequency compounds. On the bases of frequency compounds, each activation level of participants was assigned (see table 6) (11).

Table 6 – Description of EEG-frequencies and context between EEG frequencies and activations levels (11)

Frequency range in Hz	Frequency rhythm
8 - 13	alpha rhythm
14 - 30	beta rhythm
4 - 7	theta rhythm
0,5 - 3,5	delta rhythm
Frequency rhythm	**Activation level**
alpha rhythm	relaxed awake condition
beta rhythm	impulse perception
theta rhythm	snooze
delta rhythm	sleep

During a relaxed awake condition and closed eyes, there is a dominant alpha rhythm at cortex parietal and occipital in 85% of the population (12). These can be determined using an analyze of spectral power distribution. Through an exposure of original noise and modified noises of the chosen kitchen appliance, it is expected that there will be a change of activation level and consequently of alpha waves. These changes were clearly observed through the frequency variation of dominant power density and/or through a different distribution of power density at cortex. Basic condition was set to be power density distribution during a relaxed awake condition with closed eyes. Changes to the basic condition should represent the level of psycho-physiological stress of noises of kitchen appliances.

6.2 Silence Phases

A dominant power density distribution of alpha waves at cortex parietal and occipital was measured during a relaxed awake condition with closed eyes during “silence 2” and “silence 3” phases. These two states represent a comparable status and a confirmation to a relaxed awake condition by (12). Minor differences during “silence 2” and “silence 3” are obviously due to temporal load. During “silence 1”, a high power density distribution of alpha waves was measured at cortex frontal. This could be influenced e.g. by nervousness, strain or expectation. Across all conditions, influence of noise on activation level was analyzed for the duration of 7 to 15 minutes (see table 5).

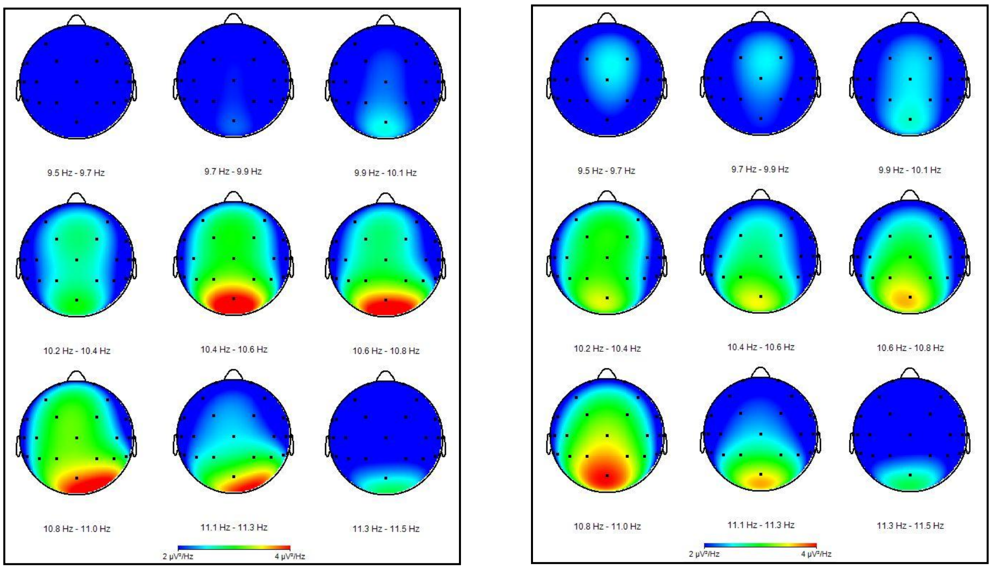

Figure 3 – Power density distribution (experimental subjects average) during “silence 2” (left) and “silence 3” (right); limitation of dominant alpha waves

6.3 Noise Phases

Power density distribution significantly changed during different noises. Especially during “Variation A” (original noise) a dominant power density distribution was measured at cortex occipital to central-parietal (see figure 4). Differences of power density distributions between silence and “Variation A” were clearly detectable. For the optimized “Variations C” and “Variation D” identifiable was a convergence of power density distribution to relaxed awake condition. Highest convergence was observed in “Variation D” (see figure 4).

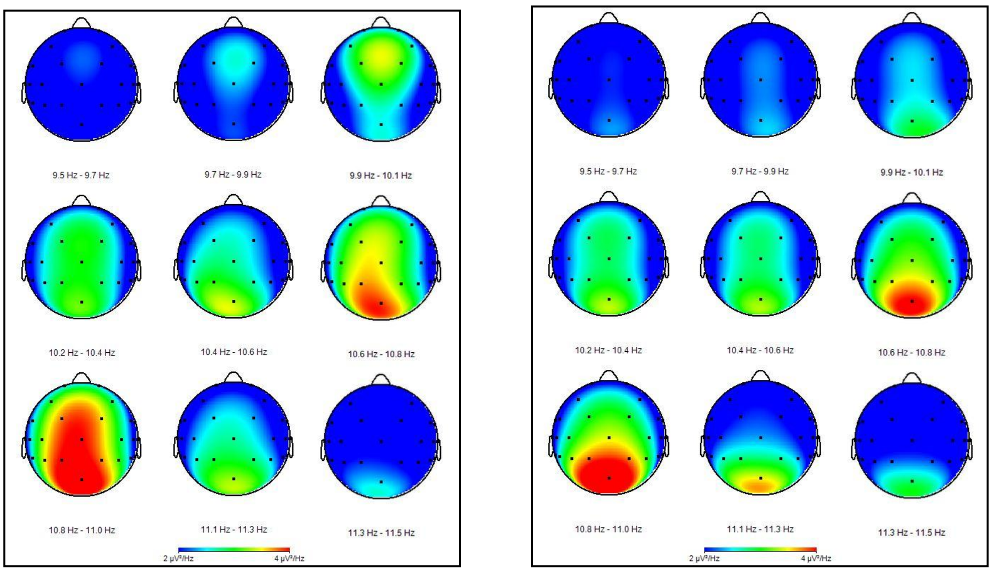

Figure 4 – Power density distribution (experimental subjects average) during “Variation A” (left) and “Variation D” (right) during 7 to 15 minutes time period; limitation of dominant alpha waves

Besides power density distribution, frequencies of dominant alpha waves also changes. This effect was detected through a comparison of the three silence phases. Dominant power density was in a lower frequency band at the beginning of the investigation. At the end of the investigation, the dominant power density was shifted to a higher frequency. The increase of dominant alpha waves pointed to a higher psycho-physiological stress.

7. CONCLUSIONS

Classification of different household and kitchen applications in view of noise emission becomes increasingly more important. This research paper provided specific improvements to reduce noise emission up to 12 dB. Furthermore, influence of damping, decoupling and encapsulation were analyzed in view of noise excitation reduction. In detail, damping reduced noise emission up to 3 dB. In combination with decoupling, noise emission could be reduced up to 7 dB.

In addition to the achieved reductions of sound power level, psychoacoustic parameters were influenced simultaneously. Especially, loudness and roughness of noise emission were reduced. These effects can be explained through a lower sound power level and quantitatively lower fluctuations of sound power level. Furthermore, sharpness was influenced by composition of frequency spectrum. Smaller shares of high frequencies in comparison to lower frequencies result in a reduced sharpness.

Influences of modified sound level and sound quality were investigated in objective measurements of psycho-physiological stress using spontaneous EEG. Differences of spontaneous EEG indicated significant differences between “original noise” and “optimized noise”. The power density distributions of the “optimized noises” as compared to the “original noise” come closer to the distribution when subjects are relaxed-awake. The result showed that modifications have been successful as measured through an objective mean. The results are more pronounced, when there are larger differences in sound power level. As such, the optimization of the “optimized noise” with a decoupling and damping is better than the “optimized noise” with only decoupling.

In sum, this research paper showed that simple and common acoustical optimizations can be used for household appliances. The impacts of acoustical optimizations on sound power level and psychoacoustic parameters influence the psycho-physiological stress. Measurement of psycho-physiological stress can in turn be used, to validate, to proof and to analyze acoustical optimizations.

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