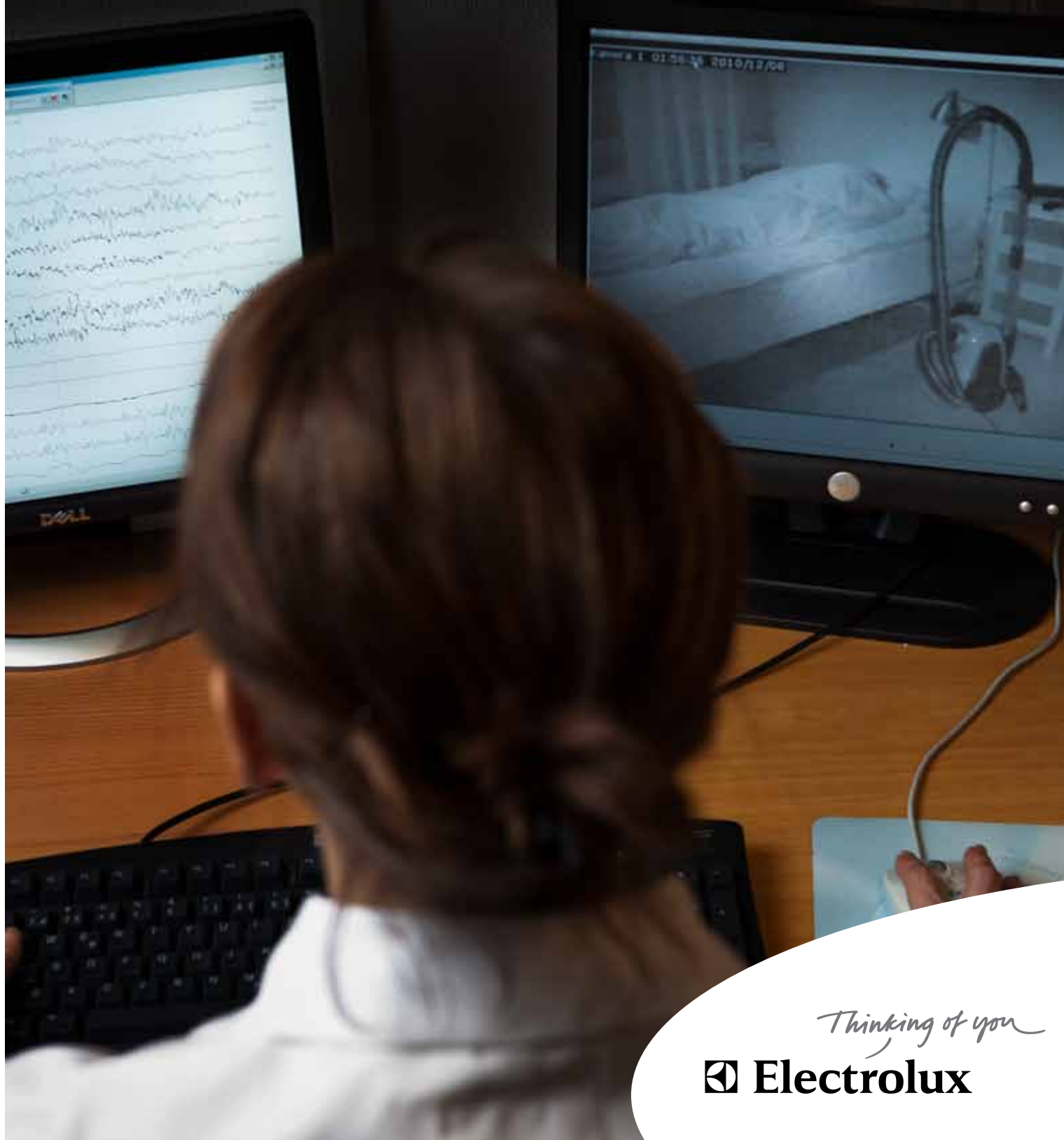


Electrolux Vacuum Cleaner **Polysomnography Study**



Thinking of you

 **Electrolux**

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Executive summary

Electrolux mission is to constantly develop home appliances that correspond with how people actually live. Consumer insight reveals that it is no longer the time of day that dictates when people choose to do the cleaning. Cleaning is rather performed any time an opportunity arises, and may very well be done late at night. The purpose of this study was to explore how vacuum cleaner sound affects sleep quality. During two nights, the nocturnal sleep of two test subjects was studied through polysomnography, monitoring brain activity, muscle tensions, eye movements and a number of other variables. The test subjects were exposed to the noise of a vacuum cleaner when falling asleep. They were also subjected to the noise while sleeping. Two of three attempts to fall asleep with the vacuum cleaner turned on succeeded. Also, 18 out of 21 times, the test subjects remained asleep as the vacuum cleaner was turned on. The test subjects showed no or little reaction to the vacuum cleaner sound while in a deep sleep stage.



Image 1:

Image from infrared surveillance camera used for monitoring the test subjects while sleeping.

Introduction

Background

Consumer aversion to unwanted and irritating noise in their homes has fueled the development of home appliances that operate more quietly and/or produce sounds in frequency ranges that are more pleasant to the human ear.

Electrolux mission is to constantly develop home appliances that correspond with how people actually live. Vacuum cleaner noise is rated as the most disturbing in the home environment by consumers. As compact living and open planning solutions become more common, vacuum cleaners – like any other home appliance – must become compatible with other activities in the home. To meet these new needs, Electrolux developed the UltraSilencer vacuum cleaner model, which generates the lowest dB-value on the market.

Electrolux consumer insight also reveals that it is no longer the time of day that dictates when people choose to do the cleaning. Cleaning is rather performed any time an opportunity arises, and may very well be done late at night. In order to gather further insight for future development, and gain better understanding of reactions to the UltraSilencer sound, Electrolux conducted a vacuum cleaner test together with a professional sleep study centre.

Purpose of the study

The purpose of the study was to explore how sleep is affected by the sound of a vacuum cleaner. The limited size of the study rules out definitive conclusions on how vacuum cleaner noise affects our sleeping patterns. It does however enable testing if a vacuum cleaner can be used without waking a person from sleep. Thus, two concrete questions were posed at the outset of the study:

1. Is it possible to fall asleep to the sound of a vacuum cleaner?
2. Is it possible to keep sleeping when a vacuum cleaner is switched on?



Image 2 and 3:

Attaching electrodes to monitor brain activity, eye movements and muscle activity.

Method and study setup

Method

A sleep study, also known as polysomnography (PSG), is a test performed in order to record the biophysiological changes that occur during sleep. During a normal night, a person's sleep profile is constituted by a succession of cycles starting with light sleep, followed by deep sleep (recovery sleep with no movements) and ending with REM sleep – the last stage characterized by rapid eye movements, dreams and muscle “paralysis” to avoid acting out the dreams. Studying different signals, one can establish whether a test subject is sleeping or not, and in which stage of sleep he or she is in. In this study, a range of body functions were monitored.

Brain activity was measured through an electroencephalogram (EEG). Sixteen electrodes were attached to the scalp, allowing measurements of electric activity in the cortex.

Eye movements were measured through electrooculography (EOG). This was done by attaching four electrodes near the eyes of the test subject, allowing measurement of movements in both horizontal and vertical directions.

Muscle activity in the chin was measured through electromyography (EMG). Two electrodes were placed under the jaw line. During REM sleep, chin muscles are relaxed. Thus, together with EEG and EOG, measuring muscle activity is a good indicator of what sleep state a test subject is in.

Heart rate, movements and respiration were measured by the employment of a Sensor Pad placed under the mattress.

Snoring sounds were recorded by placing a microphone next to the test subject's head. Two night vision cameras were placed by the foot end of the bed, visually monitoring the two test subjects during the night.

The signals were measured continuously during the night, rendering a polysomnogram, a graph depicting the transition between different stages of sleep.

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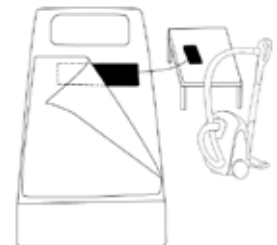


Image 4:
Placement of Sensor Pad.

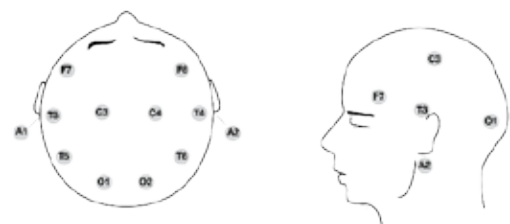


Image 5 and 6:
Electrodes were attached according to the “10–20 system”, a conventional method for applying scalp electrodes in the context of an EEG test.

Study setup and procedure

The sleep study was conducted during two consecutive nights from the 7th–9th of December 2010. Two test subjects, one male and one female, 29 and 30 years old respectively, with no documented sleeping problems, were recruited for the study. Both test subjects spent two nights at the sleep centre. The study was performed at the sleep study centre SDS Kliniken in Gothenburg, Sweden.

Observations were continuously recorded during the night by a biomedical analyst watching the real time data registrations and following the test subjects through the infrared surveillance cameras. Any response to the vacuum cleaner distraction could be registered in real time by studying the signals from the polysomnography. Arousals (a change of sleep stage from deeper to more shallow sleep, change of heart activity, body movement etcetera) or awakenings could therefore be observed immediately.

During the night, the biomedical analyst repeatedly switched on the vacuum cleaner, letting it run for approximately two minutes, and then switched it off again. This was done using a remote-controlled switch placed in the control room. The vacuum cleaner was switched on during different times in the night and during different sleep stages.

Each night's sleep profile was created offline by calculation of various parameters such as: time to fall asleep, total length of time asleep, sleep efficiency, number of awakenings per sleep hour, number of shifts between different sleep stages, number and length of different sleep stages.

In the study, interest was focused not only on the reaction when switching the vacuum cleaner on, but also when it was turned off, and whether a possible reaction lasted during the whole period when the vacuum cleaner was running.

Apart from the vacuum cleaner noise, the special environment of a sleep study centre and the polysomnography equipment can affect sleep quality. In response to this challenge, only one of the two persons had the vacuum cleaner placed by their bed each night. On night two, the persons subjects switched rooms. Using this technique, one person acted as test subject while the other acted as a reference, or control. Any possible effects from sleeping in a new environment (e.g. the so-called "first night effect") could thus be detected.

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Image 7:

Raw data from the test displaying respiration and heart rate while being exposed to the vacuum cleaner sound.

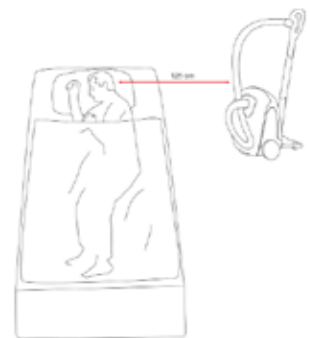


Image 8:

Drawing depicting the placement of the vacuum cleaner.

Chronological test results

Night 1

Male test subject (with vacuum cleaner)

The man acted as test subject during the first night. The electrodes were attached to his scalp about 30 minutes before bed time and the vacuum cleaner was positioned approximately 125 centimeters from the pillow. The vacuum cleaner was turned on as he switched off the bed light at 23:16. He did not manage to fall asleep with the vacuum cleaner turned on. The apparatus was turned off at 00:04, but he remained awake for another 59 minutes. His sleep was fragmented and unstable even when the vacuum cleaner was switched off.

During the night, the vacuum cleaner was switched on six times. On four of these occasions, the test subject reacted. During two attempts, while in deep sleep stage, the test subject remained asleep with no reaction to the vacuum cleaner. Three of the six attempts were done during deep sleep. The test subject was in REM sleep only for a short period during the night.

“The first night I had trouble falling asleep with the vacuum cleaner on. And even when the vacuum cleaner was turned off, I still had trouble falling asleep.”

Female test subject (without vacuum cleaner)

The woman spent the first night without the vacuum cleaner in her room. Electrodes were attached approximately 30 minutes before bed time. The light was turned off at 00:59. She fell asleep after only 3,5 minutes but woke up again for 40 minutes.

“The preparations with the electrodes weren’t so uncomfortable, but sleeping with them was quite different. I had trouble falling asleep. I think it was the whole situation. I was quite warm and I felt uncomfortable with the electrodes on.”

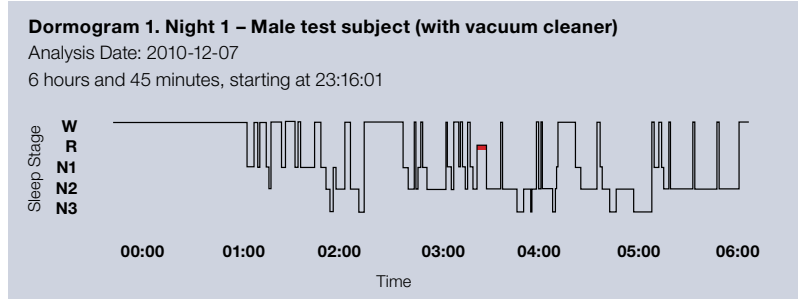
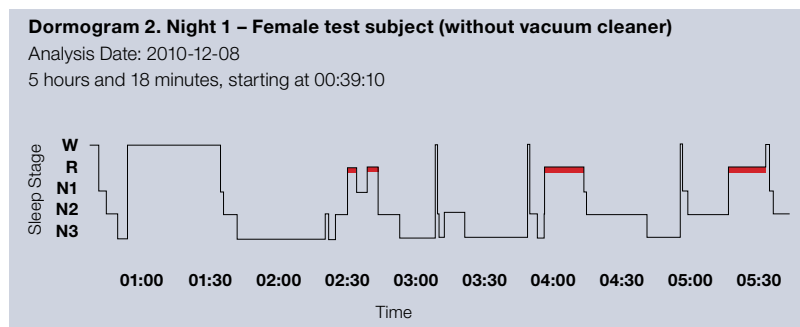


Table 1. Night 1 – Male test subject (with vacuum cleaner)
Vacuum cleaner switched on 6 times.

Sleep stage	Number of times switching on vacuum cleaner	Number of attempts with reaction	Number of attempts with no reaction	Comment
Awake				Could not fall asleep with vacuum cleaner running.
Stage I	1	1	0	
Stage II	2	2	0	
Deep sleep	3	1	2	
REM sleep	-	-	-	Only short period of REM sleep, not sufficient enough to perform test.



Night 2

Female test subject (with vacuum cleaner)

The woman spent the night with the vacuum cleaner in her room. Electrodes were attached about 30 minutes before bed time. The vacuum cleaner was switched on and the bed light was switched off at 23:37. It took 9,5 minutes for her to fall asleep. The test subject woke up because she was coughing after some minutes but then fell asleep again with the vacuum cleaner still running.

Waking attempts were performed by switching on the vacuum cleaner 15 times during the night. Five attempts were made during REM sleep. In all of the attempts, the test subject remained asleep. In total, she reacted at six occasions and showed no reaction at nine occasions.

“Night two was actually better. I fell asleep with the vacuum cleaner on. I remember dreaming something about a bus station.”

Male test subject (without vacuum cleaner)

The man spent his second night without the vacuum cleaner in his room. Electrodes were attached about 30 minutes before bed time. Bed light was switched off at 23:06. He took 36 minutes to fall asleep.

“I slept really good on night two. I fell asleep pretty fast, I was more used to the situation. I slept the whole night through.”

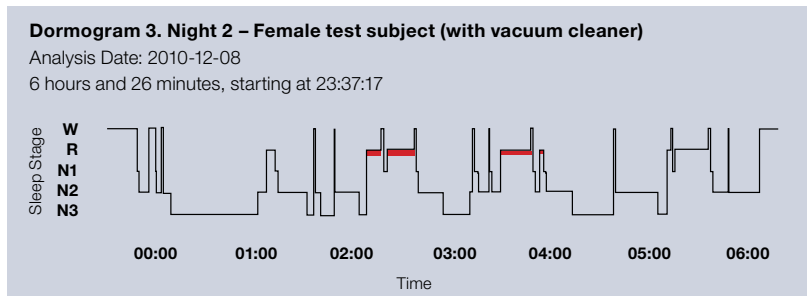
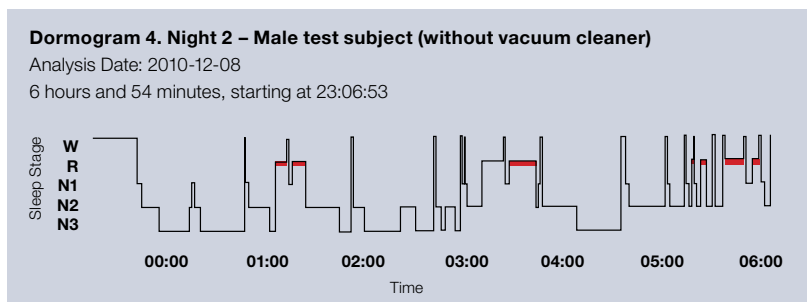


Table 2. Night 2 –Female test subject (with vacuum cleaner)
 Vacuum cleaner switched on 15 times.

Sleep stage	Number of times switching on vacuum cleaner	Number of attempts with reaction	Number of attempts with no reaction	Comment
Awake				Fell asleep, woke up coughing, fell asleep again.
Stage I	2	1	1	
Stage II	5	3	2	
Deep sleep	3	0	3	
REM sleep	5	2	3	



Summary of results

When the woman had the vacuum cleaner in her room during the second night, she had the highest level of sleep efficiency, 97%, of the total of four nights (two nights per person). During this night, 15 attempts to wake her up were made. The man's first night was the night with the lowest level of sleep efficiency, 72%.

In total, the test subjects fell asleep with the vacuum cleaner running in 2 of 3 attempts. The woman fell asleep, woke up because of cough, and then fell asleep again.

The test subjects remained asleep in 18 out of 21 times when the vacuum cleaner was turned on.

Both test subjects stated that their quality of sleep during the second night was better than it was during their first night.



Image 8:

The control room at SDS Kliniken during night monitoring and real time analysis. Biomedical analyst Lisa Sellersjö.

Image 9:

The diagrams depict the proportion of successful attempts where test subjects remained asleep when starting the vacuum cleaner.

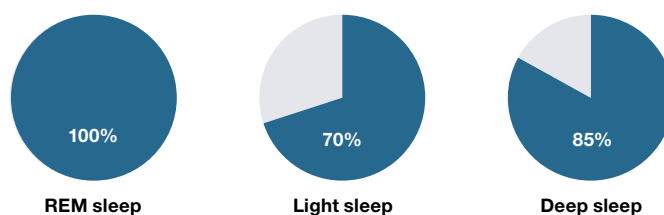


Table 3. Sleep profiles in summary

	Night 1 – Male (with vacuum cleaner)	Night 2 – Female (with vacuum cleaner)	Night 1 - Female (without vacuum cleaner)	Night 2 - Male (without vacuum cleaner)
Bed light switched off	23:16	23:37	00:59	23:06
Awakening	06:01	06:04	05:58	06:01
Time to fall asleep (min)	107	9.5	3.5	36
Number of sleep cycles	1	4	3	4
Awakenings per hour	6.7	2.1	1.1	2.7
Sleep efficiency (%)	72	97	86	87
Amount of sleep time (min)	216	366	272	362
Share of deep sleep (%)	12	31	40	33
Time until deep sleep after falling asleep (min)	50	21	7.5	12.5
Share of REM sleep (%)	3	21	16	20
Time until REM sleep after falling asleep (min)	139	79	107	82
Number of shifts between sleep stages per hour	15.7	8.7	6.8	10.8

Conclusions

This study was conducted in order to explore how vacuuming noise can affect quality of sleep. A small study like this cannot constitute a base for general conclusions, but the results can be indicative of the amount of disturbance, and they can show whether falling, and remaining, asleep is possible with a vacuum cleaner running.

The two test subjects both claim that the “first night effect”, the plausible effects due to the special context in which the study took place, had importance for their quality of sleep. They both state that their second night was better, even though one of the test subjects had the vacuum cleaner in her room during this second night. The highest level of sleep efficiency during one night was measured with the vacuum cleaner in the room, turned on at 15 occasions.

In summary, this study shows that it is possible to fall asleep with a vacuum cleaner turned on in the same room. It also shows that it is possible to remain asleep as a vacuum cleaner is switched on.

As the test subjects demonstrated no or little reaction when in the deep sleep stage the study indicates that vacuuming is preferably performed while a person is in deep sleep, to be the least disturbing.

