# Emotional Responses to Sounds Depend Mainly on Sound Level

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**Summary**
We measured electrodermal activity as an indicator of emotional arousal elicited by sounds of different emotional content and presented at different sound levels, from different directions and at different perceived distances. Sounds comprised low and high arousing sounds from a sound data base as well as noise and self-recorded voice sounds. We tested the hypotheses that sound coming from backwards should arouse more than sound coming from the front, and that sound perceived as coming from a close source would elicit more arousal than sound perceived as originating from a point far away from the observer. In addition, we compared the influence of sound intensity and emotional content. The results did not support our hypotheses. The physical sound level played the major role in determining the amount of arousal elicited by a sound, regardless of direction or distance. In our study the emotional content of the sound was less relevant than has been reported in the literature.

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## 1. Introduction

Sounds can have great effects on the emotional state of those who are exposed to them. Sounds may calm, or sounds may arouse. It is an interesting question which features of a sound make it more or less arousing. Several acoustical features come to one's mind, such as loudness and abruptness of onset. Spatial features may play a role such as the direction from which the sound comes, or the distance of the sound source. Last but not least the emotional content of the sound could be important. It seems reasonable to suppose differences in the emotional reaction to a sound originating from an aggressive act, say, a brawl, in contrast to a scene which is perceived as peaceful such as birdsong.

A classical measure of the arousal of a person is her or his electrodermal activity (EDA) [1]. As loud sounds arouse more than soft sounds, the EDA induced by a sound should clearly depend on its loudness. This has been demonstrated several times with laboratory stimuli such as noise bursts [1]. However, the dependency of EDA on sound intensity has up to now not been shown for environmental stimuli such as the International Affective Digitized Sound (IADS) database [2]. It has even been denied that such an effect exists. The authors of the IADS database claim [3] that the emotional content of a sound is more relevant. They found that high arousing sounds induce more EDA than low arousing sounds. A comparison of the strength of this 'content effect' as compared to the 'loudness effect' was, however, not possible because the intensity of the stimuli was not controlled for, neither varied.

Spatial impact on EDA has not been studied much. Given that the auditory system is a warning system that can alert the listener of events outside of her or his field of view one could argue that sounds coming from behind should elicit more EDA than sounds coming from ahead. A weak effect of this kind has indeed been found for 'natural human sounds' but not for other sounds such as 'natural animal' and various types of 'artificial' sounds [4].

Another spatial variable is the distance of a sound. One could argue that close sounds should elicit more arousal than distant sounds, because close sounds indicate an event that might interfere very directly with the listener. To our knowledge there has been no study on the effect of the perceived distance of a sound on the EDA elicited by this sound. The power of a sound source must be known to the listener in order exploit the sound intensity correctly for an estimation of the sound's distance. However, the original power of a sound source can only be derived from the sound's structural properties.

The following three experiments will test the influence of sound source location, content and intensity. The first two experiments employ environmental sounds of equalized intensity and vary their spatial location, whereas the third experiment will test environmental sounds at different sound levels.

## 2. Experiment 1: Direction of Sound

In order to test the hypothesis that sounds from behind arouse more than sounds from ahead we studied the EDA elicited by sounds coming from different directions.

### 2.1. Method

The experiment took place in a soundproof cabin. Six speakers were placed in a circle of 50 cm radius at φ = 0°(front), 45°, 135°, 180°(back), 225° and 315° around the head position. For a pilot study we used all 111 sounds of the IADS database. These sounds are of about six seconds duration and come with ratings of valence, arousal and dominance. Twenty participants rated the basic emotions elicited by these sounds. We selected 12 sounds for the main experiment such that three categories were filled with four sounds each, namely the categories high fear high arousal (HFHA), low fear high arousal (LFHA), and low fear low arousal (LFLA). As a fourth category four samples of white noise (NOISE) of the same duration were added. All 16 sounds were equalized to the same RMS power. They were checked with a digital sound level meter to be equally loud for all speakers at the head position.

Participants were attached to the physiological measurement system and placed on a chair with a small adjustable head-rest ensuring that the participant's head was placed in the middle of the speaker circle throughout the experiment. Participants listened to each of the sixteen sounds coming once from each of the six directions (96 trials in total). During sound presentation they were asked to move as little as possible in order not to disturb the EDA measurement. Four seconds after the sound a response screen appeared to indicate the direction from which the sound was perceived.

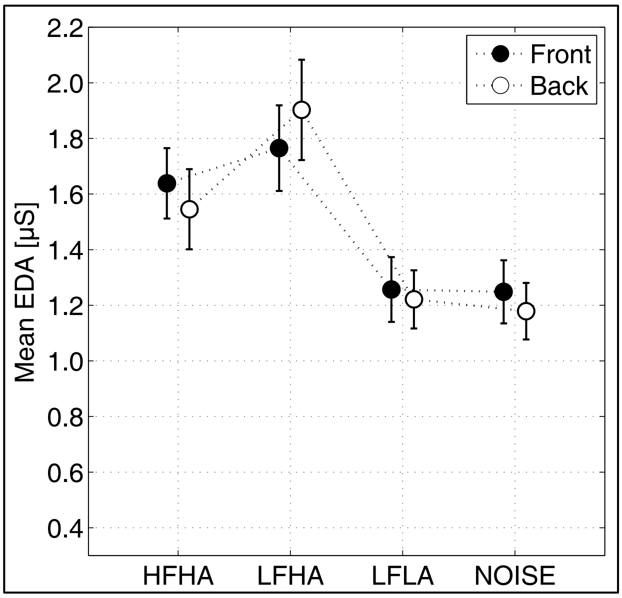


Figure 1. EDA reactions for the four stimuli categories (high fear high arousal HFHA, low fear high arousal LFHA, low fear low arousal LFLA, noise) averaged over all front and all back directions. The error bars show the standard error of the mean.

EDA was analyzed with the Ledalab software package [5] (www.ledalab.de). We determined the so-called "integrated skin conductance response" in the time window starting one second after stimulus onset and ending six seconds after stimulus onset.

Twenty-four psychology students of the University to Kiel participated in this study for course credit. Four students were excluded from analysis because they did not meet the criterion of finding at least 90% of the directions of the sounds correctly. Finally the sample contained ten male and ten female participants (age 22.6 ± 3.4 years).

### 2.2. Results

An Repeated Measure Analyses of Variance was conducted with the fixed factors fear (high/low), arousal (high/low) and direction (6 positions). Neither the factor fear ($F(1,448)= 2.13$, $p=0.145$) nor the direction ($F(5,448)=0.33$, $p=0.896$) nor the interaction of both ($F(5,448)= 0.47$, $p=0.801$) turned out to be significant. The factor arousal showed a significant difference ($F(1,448)=18.90$, $p=0.00 < .001$) for high (HFHA+LFHA) vs. low arousing sounds (LFLA+NOISE).

Figure 1 shows the results with the six directions grouped together in two blocks, namely 'Front' and 'Back'. No systematic effect of direction can be found. The means for the high arousing stimuli are higher than for the other two categories. This result concerning arousal supports prior findings and ensures that the method was adequate to elicit and measure arousal.

## 3. Experiment 2: Perceived Distance

Sounds coming from a close distance are louder than the same sounds coming from farther away. But what about sounds that despite originating from sources at different distances have the same intensity at the site of the listener? Would a soft sound coming from a close source arouse more than a loud sound coming from a distant source, alerting the listener that something is going on very close to her/him? In order to test this hypothesis we measured the EDA in response to close and distant sounds.

### 3.1. Method

The perceived distance of a sound depends primarily on the intensity of that sound. For different sounds, however, the same intensity will not necessarily result in the same perceived distance. A second factor of no less importance is the absolute power of the sound source itself. For laboratory sounds, the intensity of the sound source is not known to the listener. Environmental sounds, however, have a natural sound source power that is assumed to be known to the listener.

One of the sound sources best-known to human listeners is human speech. Speech may be uttered at several intensities. However, several characteristics of speech (e.g. spectral slope) change as the speaker changes the power of her/his speech. As a consequence, listeners are pretty good at estimating the original speech intensity and hence the distance of the speaker [6].

To gather emotional stimuli of different distances a pilot study was conducted. Six emotionally loaded words spoken by seven different speaker were recorded in a sound proof cabin. Each speaker produced each word in four different volumes (1 - soft, 2 - normal, 3 - loud and 4 - screaming) with a fixed recording distance of 50 cm. Ten participants rated these stimuli concerning their arousal and valence. Two words were excluded because of their low arousal scores. One speaker was excluded due to the deviating mean level of her speech. Finally we used the recordings of two positive and two negative German words spoken by three male and three female speakers. The selected recordings were equalized to the same mean peak amplitudes of 70db SPL. The difference between the original intensity and the equalized intensity can be interpreted as a manipulation of the perceived distance of the sound source, reducing or enlarging the original distance to the virtual distance that was our independent variable.

The EDA recording setup was the same as for Experiment 1. This time, however, recordings were presented via headphones. The four words were presented from each distance once by each of the recorded speakers. The resulting 96 stimuli were presented in randomized order, each followed by four seconds of silence and a subsequent response screen asking for the perceived arousal and valence as well as a the perceived distance of the sound (logarithmic slider from 0 to 20 meters).

Twenty-five psychology students of the University to Kiel participated in this study for course credit. Two students were excluded due to technical problems with the recordings. The mean age of the sample that underwent analysis was 23.8 ± 6.7 years.

### 3.2. Results

Figure 2 illustrates the success of the distance manipulation. Perceived distance increases linearly with virtual distance. While far distances are estimated pretty correctly, close distances are overestimated. It seems as if a constant term of about 50 cm was added to the virtual distance. This notwithstanding the distance manipulation can be considered successful, at least for distances exceeding 50 cm.

Figure 3 shows the EDA elicited by stimuli of the four distance categories. While for the first three distances categories a slight but non-significant tendency of higher EDA values for closer sounds can be observed, the final distance category shows the opposite trend. This distance category corresponds to the screaming instruction, resulting in speech that obviously conveyed strong arousal of the speaker. Overall it can not be said that for a given sound intensity close sounds arouse more than far sounds.

Figure 4 shows the valence and arousal ratings for the four distance categories. With increasing sound production intensity (from soft to scream) and hence with increasing virtual distance the valence ratings go down and the arousal ratings go up. The increase of the EDA values for the last

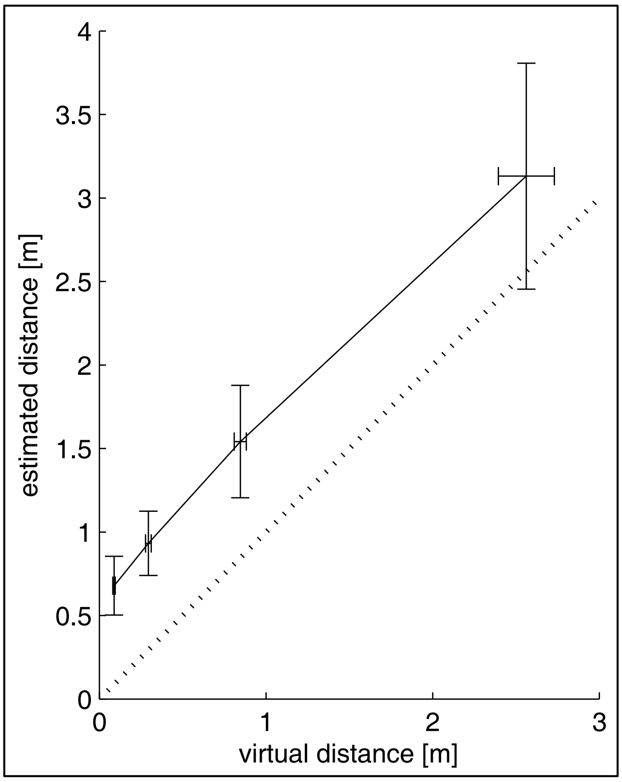


Figure 2. Mean distance ratings for the four virtual distance categories. The error bars show the standard error of the mean.

virtual distance (Figure 3) is compatible with the high arousal ratings for this distance.

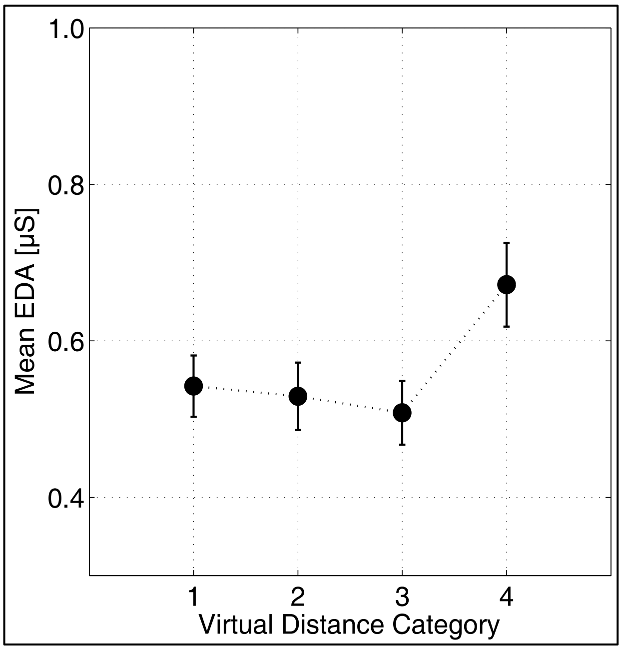


Figure 3. Mean EDA values for the four virtual distance categories. The error bars show the standard error of the mean.

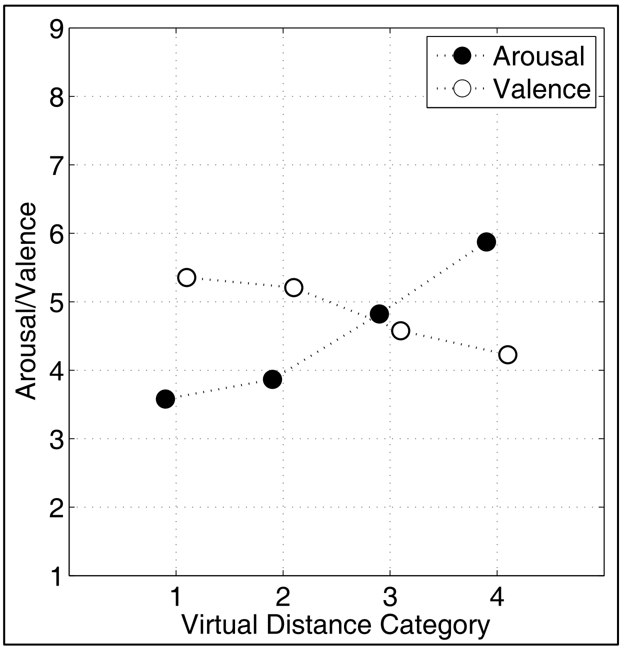


Figure 4. Valence and arousal ratings for the four virtual distance categories. The error bars showing the standard error of the mean are too close to the symbols to be visible.

## 4. Experiment 3: Content vs. intensity

A previous study [3] had shown that the EDA elicited by IADS sounds correlates with their arousal ratings. The correlation was weak (r=0.26) as compared to the correlation found when viewing pictures (r=0.81) but it was significant. The authors reported no effect of sound level on the EDA elicited by these sounds. They had, however, not controlled for the levels of the sounds but just operated with the level variation that is inherent to the sounds of the IADS database. With their equipment the range of final presentation levels was from 64 to 81 dB SPL. This is a relatively narrow range, and it does not surprise that the authors did not find effects of sound intensity.

In an unpublished master thesis Langenmantel [7] tested the role of sound intensity of environmental sounds on EDA. Langenmantel used 2-s segments of eight IADS sounds (four with low and four with high arousal ratings), equalized them to have the same well-defined RMS power, and presented them at sound intensities varying from 40 to 90 dB SPL. There was a clear-cut main effect of sound intensity. The author found also a small effect of emotional content at the higher sound intensities.

### 4.1. Method

We replicated this study, using more stimuli and returning to the original 6-s duration of the IADS stimuli. We selected eight high-arousing and eight low-arousing sounds, and in addition eight samples of white noise. All sounds were equalized to the same RMS power and presented in a sound proof booth at 40, 55, 70 and 85 dB SPL with interstimulus intervals of 14 s in randomized order. A total of 96 stimuli were presented in 32 minutes, during which we recorded EDA. Twenty psychology students participated for course credit.

### 4.2. Results

Figure 5 shows the EDA elicited by the sounds as a function of the sound level. Obviously there was a strong effect of sound level once it exceeded 55 dB SPL. Sounds at 40 and at 55 dB SPL elicit exactly the same EDA as the baseline, determined in a 5-s interval preceding the stimulus presentation (dotted line). There was no significant effect of emotional content.

## 5. Conclusions

The auditory modality serves as a warning system alerting about events that are happening outside the field of view. Therefore we had hypothesized that spatial features of a sound should modulate the orienting response elicited by these sounds such as we measure it as EDA on the skin.

We can not support our hypotheses. A weak and unreliable "direction effect" has been reported in the literature [4]. In our study we could not confirm this effect. The direction of sound arrival seems not to play a major role in determining the arousal elicited by a sound. Likewise perceived distance seems to be of no importance, at least for distances beyond 50 cm.

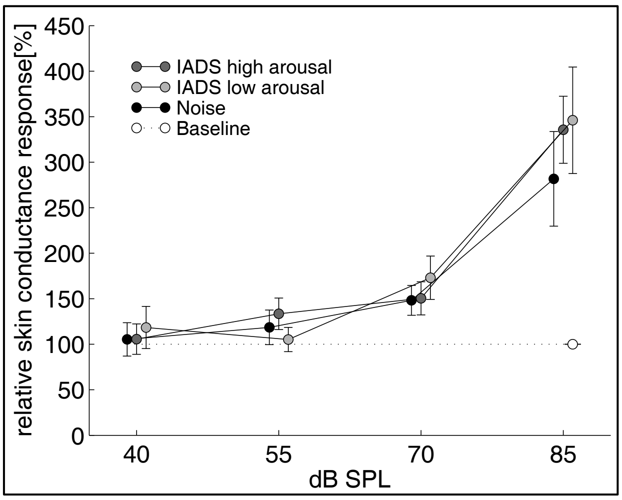


Figure 5. Mean skin conductance response for four sound intensities and three sound types. The error bars show the standard error of the mean.

The lack of a "content effect" in Experiment 3 came to us as a surprise, given that previous studies [3, 7] found such an effect and that we found a similar effect in Experiment 1 (see Figure 1). It has to be noted, however, that the "content effect" on EDA reported with IADS sounds is much smaller than the effect found with pictures [3]. Given that the original IADS sounds feature a slight correlation between arousal ratings and sound volume [3] one could suspect that to some extent content effects of IADS sounds might indeed be sound intensity effects. In the study by Langenmantel [7] the sound intensity has been controlled for. In this case other features of the sounds such as roughness might play a role. Langenmantel used only four sounds per category. Effects attributed to the categorizing criterion (arousal) might instead be due to idiosyncrasies of the four sounds selected for a category. A replication study looking for a content effect should use more sounds, presumably all sounds of the IADS database or at least a large portion of them, in order to level out possible effects due to physical properties of the selected sounds. In addition it would be interesting to look and/or control for the effects of other physical parameters that could play a role such as roughness or abruptness.

In summary we found little evidence that anything but sound level determines the orienting response elicited by environmental sounds. The effect of the emotional content (arousal ratings) is rather small. Neither the direction nor the distance of a sound seem to have any effect on the EDA elicited by sounds of a given intensity. Given that the size of the sound source is ecologically correlated to the power of a sound but not to its intensity one could argue that in acoustics size does not matter.

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