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Abstract

The present study concerns the question of possible sex differences in a multisource sound localization task. For this purpose, 45 stimuli where randomly played on one of five speakers with a fixed interval of seven seconds each. For the duration of the experiment, the stimuli were masked by background noise played on all five speakers simultaneously. A significant sex difference, favoring males could be shown for the mean localization error of all 45 stimuli. Additionally, it was investigated, whether the emotional quality of a sound is responsible for sex differences in this localization task. Therefore a rating study was conducted prior to the localization task, which yielded six classes of stimuli. Under this conditions, males outperformed females in the precision of localization for almost all stimuli classes. Our study provides strong evidence for male superiority in multisource sound localization tasks. This advantage may be related to multimodal processing of the visual and auditory system, because male superiority was shown for certain visuospatial tasks as well.

Sex Differences in a Multisource Sound Localization Task

Sex differences in cognitive abilities have been shown for different tasks (Geary, Saults, Liu, & Hord, 2000; Astur, Tropp, Sava, Constable, & Markus, 2004; Halari et al., 2006). Generally males excel females in tasks dealing with certain spatial abilities, such as the mental rotation task (Vandenberg & Kuse, 1978; Collins & Kimura, 1997). Contrariwise females exceed males in tasks on verbal fluency (Kimura Doreen, 1992) and location memory of objects (Eals & Silverman, 1994; McBurney, Gaulin, Devineni, & Adams, 1997). Different performances on certain tasks favoring either males or females are culturally universal (Linn & Peterson, 1985; Silverman, Choi, & Peters, 2007). To a certain degree those performances crucially depend on physiological parameters like hormone levels. Thus, male performance on the MRT underlies different levels of sex hormones. Higher levels of testosterone in men facilitated performance on a MRT task whereas lower levels of testosterone lead to worse results on the same task (Hooven, Chabris, Ellison, & Kosslyn, 2004). Further, a relationship between Follicle stimulation hormone (FSH) and male performance on several spatial tasks was found (Gordon & Lee, 1986). Hence, high concentrations of FSH in males led to a poor performance on those tests whereas low levels of FSH caused better performance on the same tasks (Gordon & Lee).

The level of sexual hormones not only influences the skills of males in spatial tasks but also the performance of women varies with different levels of sexual hormones. Depending on the phase of their menstrual cycle, women exhibited different skills on a three dimensional *MRT* (Hausmann, Güntürkün, Slabbekorn, Van Goozen, & Cohen-Kettenis, 2000). During their mid-luteal phase, when levels of estrogens are high, women performed poorer on visuospatial tasks than during their menstrual phase, when levels of estrogens are low (Hausmann et al., 2000; Philips & Silverman, 1997). In contrast Gordon and Lee (1993) couldn’t find such a relationship in females. Furthermore, circadian changes in testosterone levels in men seem to drive performance on spatial tasks. On the one hand Moffat and Hampson (1996) found a curvilinear relationship between circulating testosterone levels and a visuspatial task. Thus, male participants performed worst on spatial tasks early in the morning, when testosterone levels were highest. The opposite was found for intermediate levels of testosterone (Moffat & Hampson, 1996). On the other hand Silverman, Kastuk, Choi and Phillips (1999) found a positive correlation between diurnal testosterone changes in men and a *MRT*. However, a more recent study using a greater sample size couldn't find such an effect (Puts et al, 2010).

So far, the literature above considered sex related cognitive differences in visuospatial perception. But cognitive sex differences as well are found for other sensory modalities, such as the auditory system. For instance, at sound pressure levels of 3 db and frequencies of 200Hz and above, women as a group show a higher hearing sensitivity than males with both ears (Chung, Mason, Gannon, & Wilson, 1983). Those sex differences in hearing sensitivity may develop relatively early in childhood and could be shown for adults as well (Roche, Siervogel, Himes, & Johnson, 1978). Furthermore women are more sensitive to high frequency sounds above 8 kHz than males (Stelmachowicz, Beauchaine, Kalberer, & Jestaedt, 1989). In both sexes the right ear is slightly more sensitive to noise than the left ear, with a difference of two to three dB (McFadden Dennis, 1993; McFadden, 1998). Chung and colleagues (1983) showed this asymmetry in hearing sensitivity to be dependent on sex, with a greater asymmetry in males than in females. Another interesting finding (Tobias Jerry, 1965) is related to sex differences in the perception of binaural beats. The effect of binaural beats occurs, when a single tone with low frequency is presented to one ear, whereas another tone with a slightly higher frequency is presented to the other ear simultaneously (McFadden, 1998). This suggests that neural pathways, which encode time differences in both ears, must somehow collaborate at a higher level to integrate those two pure tones into one single perceived beat and that the male's auditory system seems to encode temporal factors of pure tones differently compared to women. In fact Tobias (1965) found that the ability of females to perceive binaural beats failed when the first tone was between 600 -800 Hz. However, males still had the feeling of a fusion of these two separated sounds at the same frequency range (Tobias, 1965).

Another main function of the auditory system is its ability to localize sounds in the direct environment. For this purpose it is necessary to know where a sound does come from. So to properly identify the direction of a sound in the horizontal plane two binaural cues are needed, the inter-aural time difference (ITD) and the inter-aural level difference (ILD) (Rayleigh, 1907; Blauert Jens, 1983; Middlebrooks & Green, 1991). Usually low frequency sounds, below 1000 Hz, are encoded by ITD's whereas high frequency sounds, above 1000 Hz, by ILD's. This is also known as the Duplex theory of sound (Rayleigh, 1907). But those two cues are not separated from each other. Rather, in natural environments, sounds often consist of both low and high frequencies. On the contrary, monaural spectral cues are crucial for encoding the origin of a sound as well (Hebrank & Wright, 1974; Langendjik & Bronkhorst, 2002). Langford (1994) showed a male superiority in the distinction of small differences in ITD's and ILD's. This suggests that the precision of males in sound localization tasks might be higher than the one of females. However, female performance in auditory tasks to a certain degree is influenced by different fluctuating sexual hormone levels during the menstrual cycle (Tobias, 1965; Swanson & Dengerink, 1988). For instance, the auditory sensitivity at 4 kHz in women with a regular cycle was worse during menstruation than during ovulation (Swanson & Dengerink, 1988). The detection of binaural beats in women seems to be critically influenced by their menstrual cycle as well. The perception of binaural beats was extended to higher frequencies shortly before and during menstruation, then dropped and reached a second peak around day fifteen (Tobias, 1965). In the past there have been conducted just a few studies which concerned cognitive sex differences in sound localization tasks. Lewald (2004) could show that such sex differences in sound localization might be related to possible lateralization effects in the auditory system. Though he failed to demonstrate a gender difference in two of three experimental conditions (left ear blocked, right ear blocked, both ears free, respectively), he could find a significant difference when both sexes listened with just their right ear. Males as a group showed better performance in the localization of vertical sound than females as a group (Lewald, 2004). On the contrary, females as a group localized sounds better with their left ear than males as a group but this finding didn't reach significance (Lewald, 2004). Since all the participants in this study were right handed, this finding may be grounded on gender differences in the lateralization of cognitive processes in both hemispheres. In males the left hemisphere seems to be dominant in the localization of sound in the vertical plane whereas females show a right hemisphere bias for those conditions (Lewald, 2004). Another finding (Neuhoff, Planisek, & Seifritz, 2008) in sound localization refers to sex differences in the audio-spatial perception of looming sounds. When looming sounds stopped at a certain distance from the subject, women perceived those sounds to be significantly closer to them than men. Such a bias wasn't found for sounds, which moved away from the subjects (Neuhoff et al., 2008). In a further study Bach, Neuhoff, Perrig and Seifritz (2009) measured physiological parameters like skin conductance in response to looming sounds or sounds that moved away from the subjects. Sounds that moved away from the subject caused a smaller skin conductance magnitude than looming sounds (Bach et al., 2009). Furthermore participants rated looming sounds to have a greater negative valence than receding sounds (Bach et al., 2009). A recent study (Zündorf & Karnath, 2011) dealt with the ability to localize certain stimuli in a multisource environment. For this purpose they played five different stimuli from five different loudspeakers in a quasi-random order. The task was to follow one stimulus of those five and locate its directions by either using a head response method or a manual pointer method. In the single source condition, when every stimulus was presented on one of the five boxes, respectively, no gender bias in the accuracy of localization was found. But as the subjects were exposed to the multisource condition males tended to be more precise in their responses than females (Zündorf & Karnath, 2011). The above discussed literature treated sex differences in visuospatial and audiospatial perception. It was seen that sex differences occur task-dependently. The origin for those findings seems to be grounded on hormonally caused differences in the development and architecture of certain brain regions which result in sex-dependent cognitive patterns (Kimura Doreen, 1992; Neufang et al., 2009). However, in our study we wanted to investigate possible sex differences in the localization of complex sound stimuli in a multisource sound localization task.

Due to test our hypotheses, we created an environment with different ecologically valid stimuli and background noise. In this multisource environment males on average localize those stimuli, independent from their quality, more precisely than females. Furthermore the precision in localization depends on the type of the stimulus. Unpleasant and harmful stimuli on average are located more precisely by males than by females. On the contrary, females outperform males in localization of stimuli with positive features such as baby noises or kids playing. Prior to the localization task factor analyses were performed in order to gain proper emotional attributes for each stimulus. A modified version of Rusell's circumplex model (1980) was used for the rating study (see Methods section for details).

Methods

Participants Rating Study

Participants of the rating study were 14 males (M=26.94; SD=3.36) and 16 females (M=24, SD=2.05). All of them were recruited from different universities in Vienna. They all were German native speakers.

Stimuli rating study and localization task

Forty-one sounds were selected from the *IADS* (The International Affective Digitized Sounds) database (see Bradley & Lang, 2007 for detailed information). The other four sounds were taken from a private database. To trim the sounds to a length of two seconds each the free audio software *Audacity* (audacity.sourceforge.net) was used. A noise sequence of ten minutes duration was obtained from a recording of a subway station. Furthermore every single sound and the background noise sequence itself were edited to a sample rate of 44.1 kHz and digitalized to 16bit with the same audio software. Both stimuli and background noise were normalized to -6db. They were played with *Quick Time Player* 10. The sound pressure level of the stimuli was 70db. The background noise was presented at 55db.

Material and Apparatus Rating Study

To rate the different sounds the *Python* and *Mac OSX* based Interface *Emotional Systems* (Grammer, Abend, Welke, & Holzleitner, 2013) was used. Since this was a computerized rating study three *Apple Mac Minis*® served to run the Interface. Participants used an ordinary computer mouse to drag the bars to one of 23 given pairs of opposites, at each time. The bar could be dragged anywhere on a scale from 0 to 100. Thereby subjects could attribute emotional qualities to the heard stimuli. 18 affect words were obtained from Russell (1982). The other four words were natural, dangerous, artificial and harmless. The participants heard the sounds through *Sennheiser HD201* Headphones.

Procedure Rating Study

The rating study took place at the Department of Anthropology at the University of Vienna. At first participants were asked to take a seat in front of the computer and put on the headphones. Before the experiment started, they were instructed to judge the stimuli as intuitively as possible. Participants could stop and replay every single stimulus as many times as they wished. If they weren't able to assign a proper word to the heard sound they were told to leave the bar in its original position. The 45 stimuli were presented in a random order.

In order to obtain the categories a sound belonged to, the rated items for each sound in a first step were factor-analyzed. One factor analysis was conducted for the first 18 items, the second one for the remaining four items (see Tables 1 and 2 for factor analyses with the used affect words). Three factors could be extracted from the first analysis. The second analysis yielded two factors. Subsequently the five saved regression variables were each plotted on the sound stimuli (see Figure 1-5). Thereby, every stimulus could be attached to its proper category (see Appendix C).

Insert Figure 1-5 about here

Participants Localization Study

N = 60 individuals participated in this experiment. Half (50%) of the sample were males (*M*=25.68; *SD*=3.27 years), the other half (50%) were females (*M*=23.54; *SD*=3.73). All female subjects were students from the University of Vienna. Almost all (76%) male participants were students from the University of Vienna as well. The remaining participants either were employees (13%) or worked as freelancers (11%). The majority (90%) of the participants were right handed. The remaining participants were either left handed (8.3%) or ambidextrous (1.7%). Four individuals were excluded from the experiment because of hearing thresholds over 20dB. Additionally, participants with higher mean deviations than 40° were excluded from the dataset.

Material and Apparatus Sound Localization Task

At first participants passed pure tone audiometry for the frequencies 125, 250, 500, 750, 1000, 2000, 3000, 4000, 6000 and 8000 *Hz* in a 2 m × 2 m anechoic room, using *AKG* Headphones (K-272 HD, AKG Acoustics). There were approximately 15 minutes between the hearing task and the sound localization task. In the meantime, participants could rest their ears. In this break they were asked to answer a questionnaire (see Appendix A) which included the Positive and Negative Affective Schedule (PANAS) (Watson & Clark, 1988) as well. The localization study then took place in a 6 m × 6 m absolutely dark reverberant room. Participants sat on a fixed chair, which could be adjusted in height. This allowed bringing the listener's head in line with the loudspeakers. Additionally participants wore a blindfold. Five loudspeaker boxes (Dynavox TG1000M, Dynavox Audio*)* were arranged in a semicircle (180°) with a radius of 2.5 m and a constant interval of 45° between each loudspeaker (90°, 135°, 180°, 225° and 270°, respectively). Every loudspeaker was placed on a self-built platform of 120 cm height (see Appendix B). One platform always consisted of one piece of plywood in the dimensions of 120*cm*×30*cm*×1*cm* and two pieces in the dimensions of 120cm×14,5cm×1cm. Those parts were assembled with ordinary brackets and screws (3.5mm×12mm, Z2 Spax*).* A fourth plywood plate (25cm×25cm×1cm) was mounted on top of the construction. All five speakers were connected to an USB Audio Interface (ESI Gigaport HD+) via three *RCA* Cables (two 2×2 cinch and one 1×1 chinch, respectively). The two passive loudspeakers then were connected to the two active speakers via ordinary litz wires. Afterwards every single speaker was connected to its proper analogue output on the Interface (i.e.: Speaker 1 → Output 1). Consecutively the audio interface was linked to a computer. A manual pointer method served to respond to the stimuli. Participants could determine the assumed source of a stimulus by pressing a simple pushbutton (HB15SKW01, NKK Switches), which was positioned at the back end of a rod. The rod itself was fixed to the upper part of two plasterboards. Between the two small plasterboards (10cm×8cm×3cm), which lay on top of each other, a potentiometer (PL300, novotechnik Siedle Gruppe) was embedded. The upper plasterboard was versatile whereas the lower one was attached to a solid tripod. Thus, participants could move the metal rod in the horizontal plane. All the single electronic parts were connected to an *Arduino* board (Uno Rev3, arduino.cc). The *Arduino* itself was connected to the computer via a USB cable (see Appendix D for the electronic scheme). A self-developed program (Python 2.7.2 for Mac OS X) by Grammer recorded the stimulus number, the absolute localization of the listener, the location of the sound source and the deviation with respect to this source automatically.

Procedure Sound Localization Task

At first, listeners were acquainted to the manual pointer method. For this purpose, three out of 45 stimuli were chosen and played randomly on one of each loudspeaker box successively. Simultaneously, the background noise was played on all five loudspeakers. The task was to determine the direction of the source by pointing at it. Time intervals between the stimuli were not fixed in this phase. This was done for the amount of time the participants deemed necessary and confirmed to feel comfortable with the pointing method. The main part of the experiment was quite similar to the adaptation phase. Instead of three randomly chosen stimuli all 45 stimuli were played in a random order, different for every participant. Furthermore a chosen stimulus could randomly occur on one of the five loudspeakers. Between each stimulus there was a fixed interval of 7 seconds. Background noise was played on all five speakers at once during the whole experiment. It was always presented in the same manner, starting at null seconds. Listeners were asked to localize the heard stimuli as precisely as possible with respect to their origin. The experiment lasted about eight minutes.

Data Analysis Localization Task

Since all variables were normally distributed in both groups independent sample t-tests were conducted. To compare the overall accuracy between the sexes mean absolute deviation for every single participant was computed. Furthermore the absolute deviation error with respect to every single sound was compared between males and females. The same procedure was done for every single yielded factor. Listeners who had deviations of 40° and more were excluded from the test. A possible relationship between the self-reported emotional status and the localization performance was tested by bivariate correlations. The variables of the PANAS were correlated with the overall mean deviations of the subjects and the deviations for evaluated categories of stimuli. Additionally it was investigated whether patterns in localization accuracy varied according to the different phases of the menstrual cycle. For this reason we just selected female subjects, which answered to have not used hormonal contraceptives at least during the past year. The likelihood of conception was computed using Joechle's (1973) formula (standardized day of the menstrual cycle = day of the menstrual cycle / average duration of the menstrual cycle). Consequently, gained data of twelve females, was plotted on a graph and compared to localization performance (see Figure 13). Data was analyzed with *SPSS v17*.

Results

Rating Study

Two principal component analyses (*PCA*) with varimax (orthogonal) rotation were conducted (see Tables 1 and 2). Factor analyses yielded five factors altogether. The Kaiser-Meyer-Olkin Measure of sampling adequacy indicated the first sample to be reliable for analyses, whereas the other sample was close to the recommended value of .6 (Kaiser & Rice, 1974) to be trustworthy (KMO=.869; KMO=.566). Nevertheless, it was decided to factor analyze those 4 items, because the *KMO* value for the second analysis was quite close to six. Bartlett's test of Sphericity was significant for both analyses (χ^2 (153) = 1296.87, p < .001), p<.001; χ^2 (10) =145.92, p < .001).

The analyses of the 18 items generated three factors whereby the first factor explained 50% of the variance, the second factor 22% and the third factor 13%. According to Rusell (1980) the first factor was interpreted as *arousal*, the second as *sleepiness* and the third factor was treated as *displeasure*. The *PCA* of the four remaining items produced two factors with the first factor explaining 55% of the variance and the second factor explaining 23%. The first factor was construed as threatening and the second factor as artificial. Items with factor loadings of .8 or above were selected to belong to the factor (see Table 2 for the rotated component matrix for both analyses). Scatter plots of the stimuli and the five different factors resulted in five categories of sounds which were named arousal, sleepy, displeasure, pleasure, threat and artificial.

Insert Table 1-2 about here

Sound Localization Task

The overall mean localization error for all 45 stimuli was significantly lower for males as a group, than for females as a group; $t(58) = -2.77$, $p < .01$) (see Figure 6). Furthermore a significant effect for sex with respect to the absolute deviation for a single sound was found for seven out of 45 stimuli. Thus, males as a group had significantly lower mean deviations than females for the following sounds: growl, $t(52) = -3.02$, $p < .01$; can, $t(56) = -2.13$, $p < .05$; male laugh, $t(56) = -2.39$, $p < .05$; kids, $t(57) = -2.36$, $p < .05$; man wheeze; $t(54) = -2.17$, $p < .05$; phone ring; $t(55) = -3.77$, $p < .001$, and shot, $t(58) = -2.31$, $p < .05$. For four other stimuli sex differences were marginally significant. Males as a group located the barking of a dog, $t(55) = -2.17$, $p > .05$, a sobbing couple, $t(58) = -1.87$, $p > .05$, and the sound of a machine gun, $t(56) = -1.79$, $p > .05$, more precisely than females, except for one stimulus. Females as a group had lower deviations than males in the localization of a vibrating mobile phone, $t(55) = 1.79$, $p > .05$. There was an insignificant trend ($p > .10$, respectively) for the remaining 38 stimuli favoring males for most of the stimuli, except five (see Table 3 for means and standard deviations of all sounds for both groups). Furthermore, for those stimuli which were evaluated to be arousing a significant difference was found, insofar that they were localized more precisely by males as a group, $t(58) = -3.58$, $p < .01$, than by females as a group. The same could be shown for displeasuring stimuli, $t(58) = -2.49$, $p < .05$, sounds which were described to be threatening, $t(58) = -3.58$, $p < .05$, artificial stimuli, $t(58) = -2.32$, $p < .05$, and pleasuring stimuli, $t(58) = -2.34$, $p < .05$ but not for sleepy stimuli, $t(58) = -1.49$, $p > .05$ (see figure 7-12 for bar charts). Table four represents means and standard deviations for localization errors in relation to the evaluated categories.

Insert Figure 6-12 and Table 3-4 about here

Self-reported Emotional Status and Sound Localization

The 19 items of the PANAS were factor-analyzed using a Principal component analysis (PCA) with varimax rotation (see Table 5). The Kaiser-Meyer-Olkin Measure of Sampling

Adequacy (KMO=.746) indicated the sample to be suitable for analysis. Bartlett's Test of Spericity (χ^2 (190) = 654.24, $p < .001$) suggests the correlation matrix not to be an identity matrix. Analysis yielded two factors, explaining 28% and 21% percent of the variance, respectively. Items with values above .4 were chosen to belong to a factor. Eight items loaded on the first factor, seven items onto the second factor (see Appendix for the rotated component matrix). In accordance with Watson and Tellegen (1988) the first factor was interpreted as negative affect and the second factor as positive affect. There was no relationship between the self-reported emotional status and the localization performance in all tested variables, with one exception. A negative correlation for the factor positive affect and negative sound stimuli was found, $r(58) = -.28$, $p < .05$.

Insert Table 5 about here

Menstrual Cycle and Localization Performance

A weak negative linear relationship ($R^2 = .05$) could be shown between the likelihood of conception and overall mean localization performance. Females with a higher likeliness of conception tended to be more accurate in the localization of the stimuli than women with a lower risk of conception.

Insert Figure 13 about here

Discussion

Results confirmed hypothesis in certain aspects. At first, it could be shown that males as a group had a lower overall mean deviation for all 45 stimuli than females, on average. The comparison of absolute deviation in relation to a single stimulus yielded sex differences in localization accuracy for seven of 45 stimuli. Thus, males determined the stimuli growl, can, male laugh, kids, man wheeze, phone ring and shot more precisely than women with respect to their source. A marginally significant localization bias occurred for four other stimuli. Three stimuli (dog barking, couple sobbing, machine gun) where located more precisely by males as a group than by females as a group whereas the remaining stimulus (mobile phone vibration) was recognized more accurately by females as a group than by males as a group. Furthermore, a sex bias for all obtained categories of stimuli was found, showing males to have lower mean localization errors than females. We failed to confirm the assumed superiority of females next to males when pleasurably stimuli (i.e.: kids playing, baby laughing, kids talking, female laughing and male laugh) had to be located. To a certain extent, our findings are consistent with the results of Zündorf and Karnath (2012), insofar, that there seems to be a male advantage of sound localization in an environment with multiple sources. As it has been reasoned in the introduction the auditory system uses different binaural (ITD, ILD) and monaural cues (spectral cues), to encode the direction of a sound stimulus adequately. Furthermore, it was mentioned that there are sex differences in the processing of these cues (Langford, 1994). In relation to our experiment it seems that males tend to be more capable of encoding these certain cues than females. Though, it has to be stated that, in contrast to other sound localization tasks, our experiment was conducted in a reverberant room. In such rooms the noise is resonated by the walls, which causes delays. This might contribute to confusions in identifying the proper sound source. Nevertheless, accurate localization of sound stimuli is possible in reverberant rooms, concerning the precedence effect, which describes the ability of the auditory system to somehow restore spatial information of the first arriving wave whereas the produced delays are integrated afterwards (Wallach Hans, 1949). Thereby, the original direction of a sound source can be maintained. With respect to our findings it can be suggested, that the male auditory systems might be more sensitive to changes in temporal information of complex sounds in reverberant environments.

But as seen, there is another phenomenon, which might influence the performance on audiospatial tasks, i.e. the menstrual cycle. The higher the chance of conception was, the better females performed on the task. Even though, the effect we found is fairly weak there seems to be a certain trend in the data, which is in line with the results of other experiments (Tobias, 1965; Swanson, & Dengerink, 1988). However, this effect might have been stronger if there had been a greater number of female subjects tested. Furthermore, it could be shown that participants who reported to feel less positive had larger errors in localization. This outcome seems to imply that the emotional status of a participant can influence overall performance in such experiments crucially and might explain some of the high mean deviations of participants. Furthermore, the use of the pointer method itself possibly had an influence on our results, since males and females perform differently on certain eye-hand coordination tasks. For example, males are faster in finger tapping tasks whereas females show better scores for the grooved pegboard tasks (Ruff & Barker, 1993). Concerning the pointer method males might have an advantage in handling the metal rod more precise than females. However, our outcomes suggest that cognitive sex differences not just occur for certain visuospatial tasks, but can be found for audiospatial tasks as well. This leads to the assumption that there might be multimodal processing between these two qualities.

Indeed, there seems to be some evidence for this assumption. In a newer study Zwiers and colleagues (2003) examined in how far a change in the visual modality (0.5×lenses for 1 day) led to a changes in the auditory modality as well. Their results suggest that the reducing of the visuospatial solution resulted in a comparably reduced solution of audiospatial perception, at least in azimuth (Zwiers et al, 2013). Following this finding, these two qualities must somehow act in concert. Thus, the auditory system acts as a kind of coordinator leading the visual towards a certain event within the environment (Guski, 1992). As suggested by Neuhoff (2009) and Zündorf and Karnath (2011) male superiority in audiospatial tasks might be a product of better visuospatial skills and males therefore are more capable of intrinsically encoding spatial properties of the environment. If this is true, such fundamental differences probably have evolved pretty early in human evolution. A proper environment can be found around two million years ago, when humans lived together in small hunter-gatherer groups. It seems reasonable that sex differences in spatial abilities were shaped due to different patterns of foraging in males and females (Eals & Silverman, 1994, Silverman & Eals, 2000). To localize the position of prey properly it needs certain auditory and visual spatial skills. These skills might differ from those, which are needed to gather food. The ability of males, to localize stimuli which cause arousal and such which were evaluated to be threatening more precisely than females, might fit this idea. But, since all different stimuli categories in our task, except stimuli, which were rated to be sleepy, yielded sex differences favoring males, it is not likely that these results are just caused by the semantic meaning of stimulus itself. It seems more likely that stimuli, which were evaluated to belong to the same category, share more physical properties with respect to their acoustical similarities than sounds, which don't (Staeren, Renvall, De Martino, Goebel, & Formisano, 2009). Nevertheless, the physical qualities of a sound stimulus must be encoded properly to attribute a semantic meaning to it. Following this idea it is possible that males decode the physical qualities of such categorical stimuli more precisely than females, which enables them to trigger the semantic meaning of a sound faster and to be more aware under such conditions. Linking this notion to the finding of sex differences for localization of threatening and negative stimuli might explain male superiority in our experimental setup. In a hunter-gatherer environment it could have been an advantage for males to react more accurately and faster to threatening stimuli, to avoid to get killed by predators during foraging.

However, it has been shown that sex differences in the ability of sound localization in such a multisource environment may be governed by cognitive sex differences in the processing of the physical properties of the stimulus itself. With regards to our findings, this study contributed to the understanding of auditory sex differences in multisource sound environments. Since this was one of the first experiments measuring sex differences under such conditions further studies are required to confirm our findings.

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*Table*1.

Rotated Component Matrix of the rating study. Items with factor loadings of .8 or higher belong to the factor. Note: words in this list were obtained from Russell (1980)

Items	*Component*			
	1	*2*	*3*	*4*
schwermuetig	,982			
ungluecklich	,973	-,182		
veraergert	,963	-,147	-,119	
unzufrieden	,957	-,234		
ueberdruessig	,926	-,313		
verzweifelt	,922	-,297		
nichterregt	-,268	,918		,119
traege	-,239	,883	,264	-,199
entspannt	-,418	,869	,133	
schlaefrig	,307	,858	,227	-,168
matt	-,462	,833	,111	
gelassen	-,546	,801		
unterwuerfig		,291	,901	-,165
beeinflussbar	-,182		,857	
ehrfuerchtig		,115	,842	,183
umsorgt		,254	,751	-,433
kontrolliert	-,147		,714	,596
gelenkt	,657	-,106		,667

*Table*2.

Rotated Component Matrix for the second analysis. Items with factor loadings of .8 or higher belong to the factor.

Items	*Component*	
	1	*2*
harmlos	-,944	-,107
stoerend	,889	,201
unbekannt	,446	,248
natuerlich	-,200	-,963
maschinell	,230	,949

*Table*3.

Means and standard deviations for male and female groups for all 45 stimuli.

Note: The data in parentheses represent the sound number of the stimuli.

Stimulus	*Males*			*Females*		
	N	*M*	*SD*	*N*	*M*	*SD*
Panting (104)	30	13.28	9.40	29	14.41	13.08
Puppy (105)	29	13.78	9.01	26	11.95	9.69
Dog Growl (106)	27	8.48	4.91	27	14.66	9.42
Dog (107)	28	10.79	8.28	29	16.31	12.56
Baby (110)	30	12.61	7.60	28	18.03	14.86
KidsTalk (112)	29	12.08	8.81	28	12.80	10.15
Bees (115)	28	12.19	8.92	30	17.04	13.56
BoyLaugh (220)	28	12.00	10.95	25	10.63	7.50
MaleLaugh (221)	28	11.32	6.86	30	19.14	15.99
KidsPlay (224)	30	10.60	8.10	29	16.50	10.90
Laughing (226)	29	13.81	10.08	28	10.99	8.44
Giggling (230)	29	12.22	8.80	26	15.11	12.11
M.Cough (241)	27	11.00	6.81	27	14.76	14.51
F.Cough (242)	29	12.25	9.32	30	16.77	11.43
M.Wheeze (244)	28	12.40	9.12	28	19.29	14.02
BabiesCry (260)	29	12.52	8.63	27	14.89	14.27
Yawn (262)	29	12.53	10.03	30	13.75	11.87
Whistling (270)	30	19.51	17.74	30	26.35	21.40
Scream (275)	30	12.91	7.34	29	15.32	11.33
F.Scream (277)	29	12.03	11.42	27	17.24	12.59
Ch.Abuse (278)	28	11.58	9.40	29	12.91	9.90

Fight (283)	29	10.60	8.56	29	13.80	9.65
Attack (284)	29	12.97	12.78	29	17.54	14.50
GunShot (289)	29	13.00	6.80	29	17.32	12.69
C.Sobb. (295)	30	12.29	7.51	30	17.21	12.28
Crowd (312)	29	11.70	10.20	30	15.95	12.29
R.Coaster (360)	28	13.19	10.62	28	14.16	10.57
Crowd2 (368)	30	17.23	13.92	29	14.99	11.31
Injury (423)	27	10.91	6.82	26	10.65	9.55
AirRaid (624)	29	12.59	10.49	29	14.78	12.90
Explosion (626)	30	12.16	10.17	29	14.20	12.75
BusySignal (703)	27	12.25	9.64	30	26.54	17.43
Phone (704)	29	14.02	11.51	28	13.70	10.32
Clock (708)	30	11.96	8.63	28	12.26	7.37
Buzzer (712)	28	11.42	7.78	28	13.63	12.21
Dent.Drill (719)	29	14.45	8.42	30	14.97	12.93
Walking (722)	28	16.04	14.52	28	12.01	9.11
Crash (732)	28	8.66	6.74	26	10.24	6.64
Guitar (816)	29	15.11	11.49	28	20.32	15.94
Vibration (817)	30	14.81	13.41	27	9.40	8.62
MGunburst (818)	28	9.52	5.89	30	14.09	12.25
GunShot (819)	27	10.44	7.73	30	18.82	17.30
Lighter (820)	30	14.14	11.57	28	17.22	11.55
Hello (821)	29	14.26	9.96	27	11.32	7.78
CanDrop (822)	29	9.12	5.74	29	14.96	13.60

*Table*4.

Means and standard deviations for males and females in relation to overall mean localization error and mean localization error of evaluated stimuli classes

	Males			Females		
	N	*M*	*SD*	*N*	*M*	*SD*
OverallMean	30	12,65	2,87	30	15,68	5,25
Arousal	30	12,13	3,95	30	16,87	6,07
Sleepy	30	13,35	4,08	30	15,50	6,78
Displeasure	30	12,53	3,93	30	16,16	6,96
Threat	30	11,55	3,30	30	15,22	5,44
Artificial	30	12,46	3,91	30	15,38	5,65
Pleasure	30	13,31	5,18	30	17,47	8,20

*Table*5.

Rotated component matrix for the PANAS schedule. Note: Items with .8 or higher were selected to belong to the factor

Item	*Component*				
	1	*2*	*3*	*4*	*5*
erschrocken	,873	-,112		-,150	
veraengstigt	,860			,102	,181
schuldig	,854			-,105	
feindselig	,804		-,185	,202	
beschaemt	,770		,164		,412
gereizt	,664	-,373		,207	-,276
veraergert	,583			,572	
wachsam	,106	,869			
aufmerksam		,856			
aktiv	-,156	,710	,275	,140	
entschlossen	-,130	,686		,213	
begeistert	-,206	,566	,326	,156	-,126
interessiert	-,457	,554	,148	,271	,277
stark	-,267	,524	,483	,246	,252
freudigerregt		,236	,859		,122
angeregt	,194	,104	,852		
bekuemmert		,130		,896	
stolz		,321	,252	,586	,122
durcheinander	,154	-,288	-,128	,118	,796
nervoes	,248	,226	,243		,524

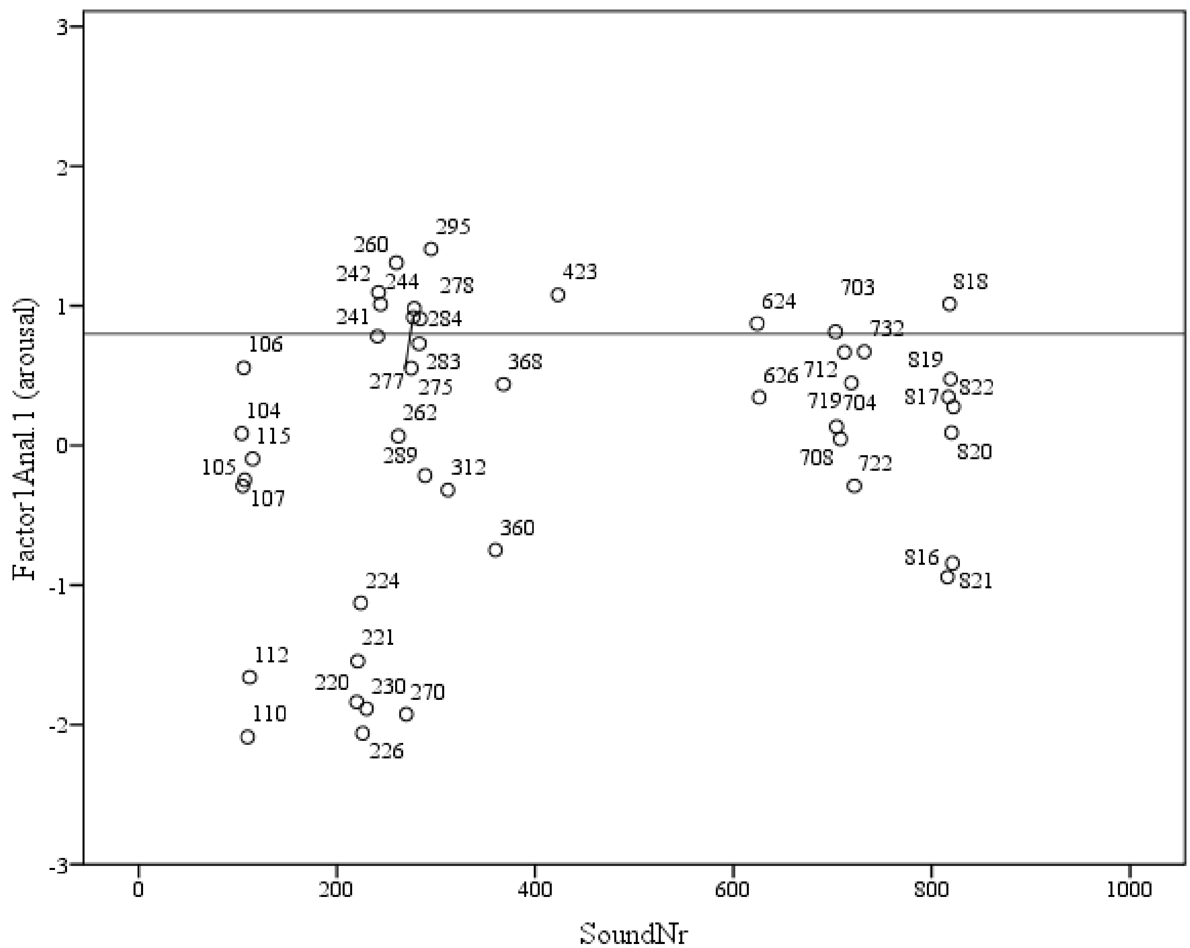


Figure 1.The sound number was plotted against the ratings for the first factor (arousal).

Note: The SoundNos. 242, 260, 277, 278, 284, 295, 423, 624, 703 and 818 loaded positive on the first factor, with .8 or higher. SoundNos. 110, 112, 220, 221, 224, 226, 230, 270 and 821 were interpreted as pleasure.

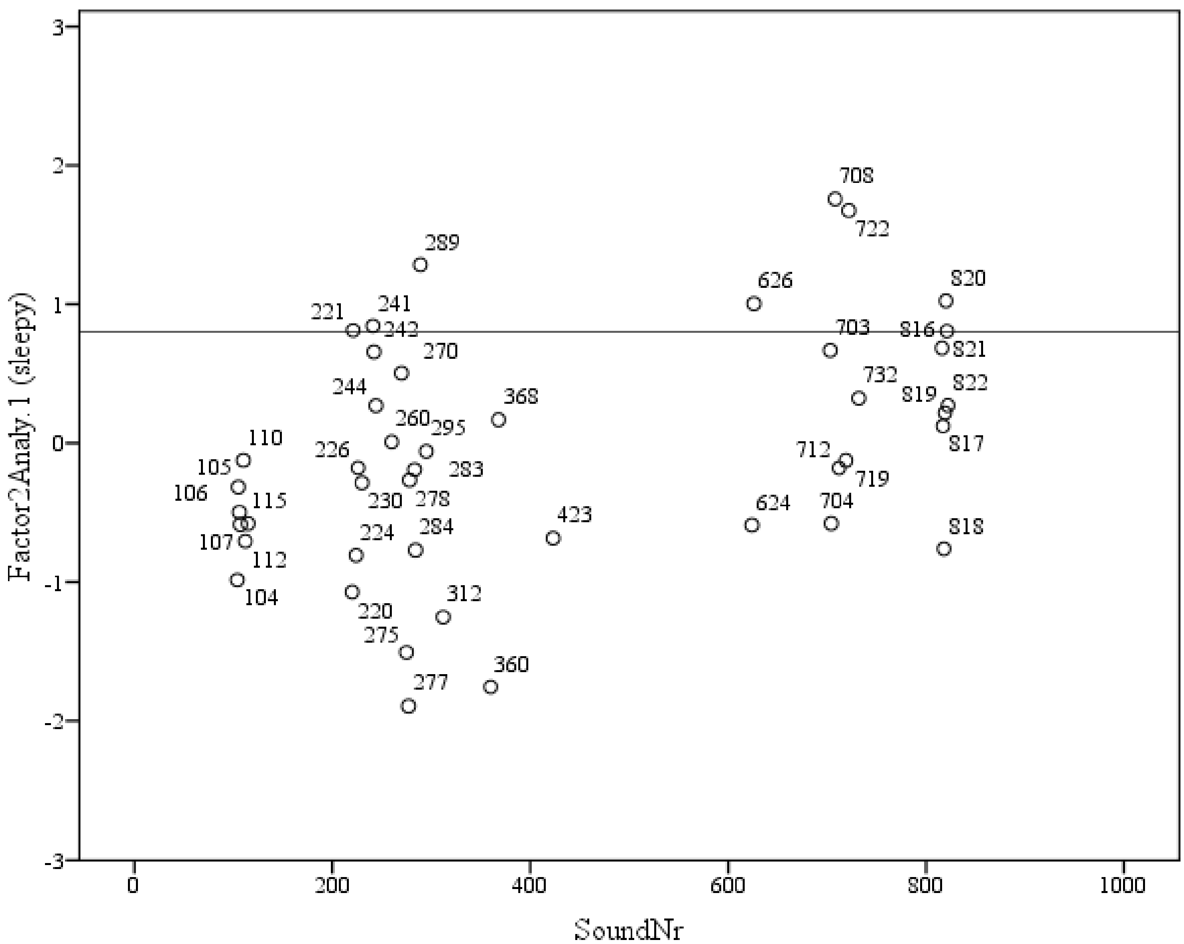


Figure2. The sound number was plotted against the ratings for the second factor (sleepiness.).

Note: The SoundNos. 221, 241, 289, 626, 708, 722, 816 and 820 loaded positive on the first factor, with .8 or higher

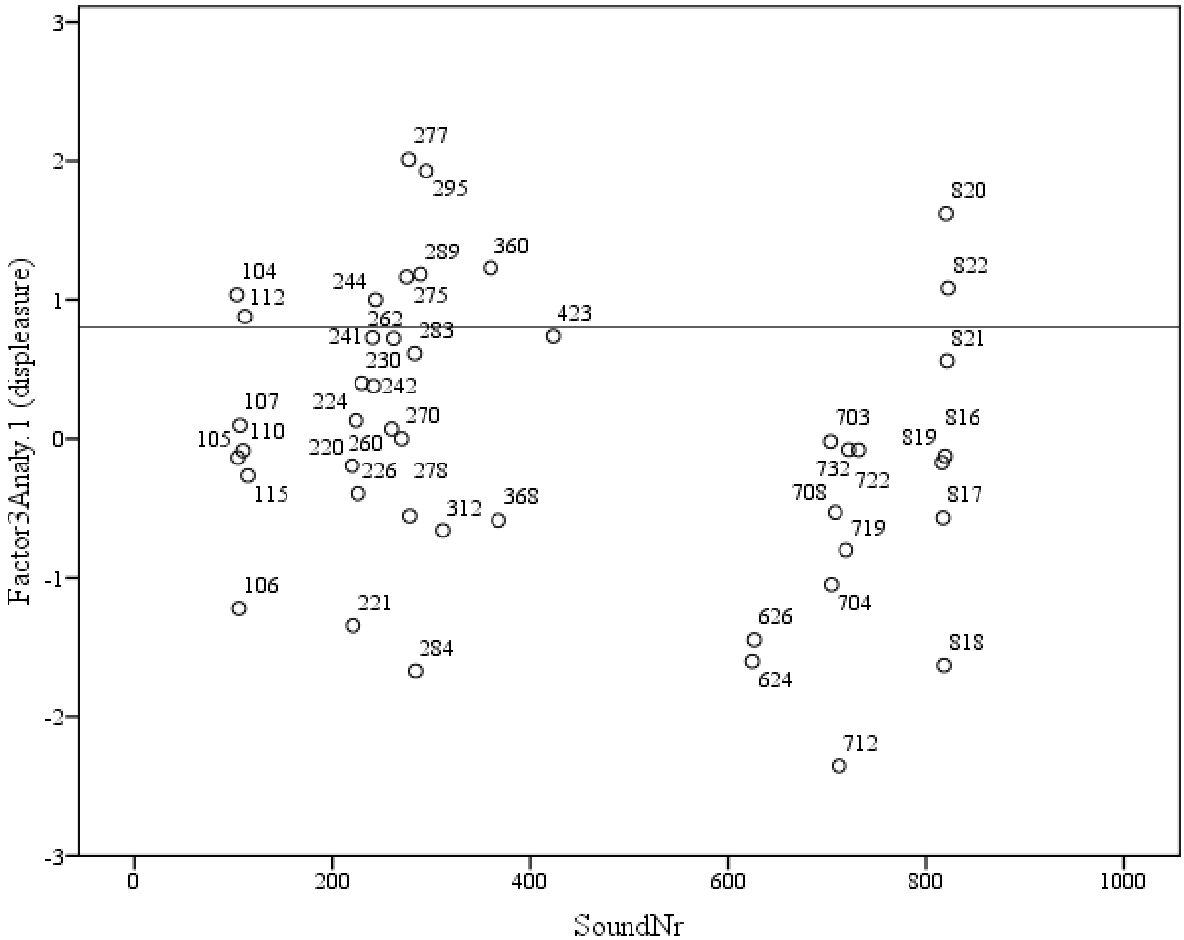


*Figure*3. The sound number was plotted against the ratings for the third factor (displeasure).

Note: The SoundNos. 104, 112, 244, 275, 277, 289, 295, 360,820 and 822 loaded positive on the first factor, with .8 or higher.

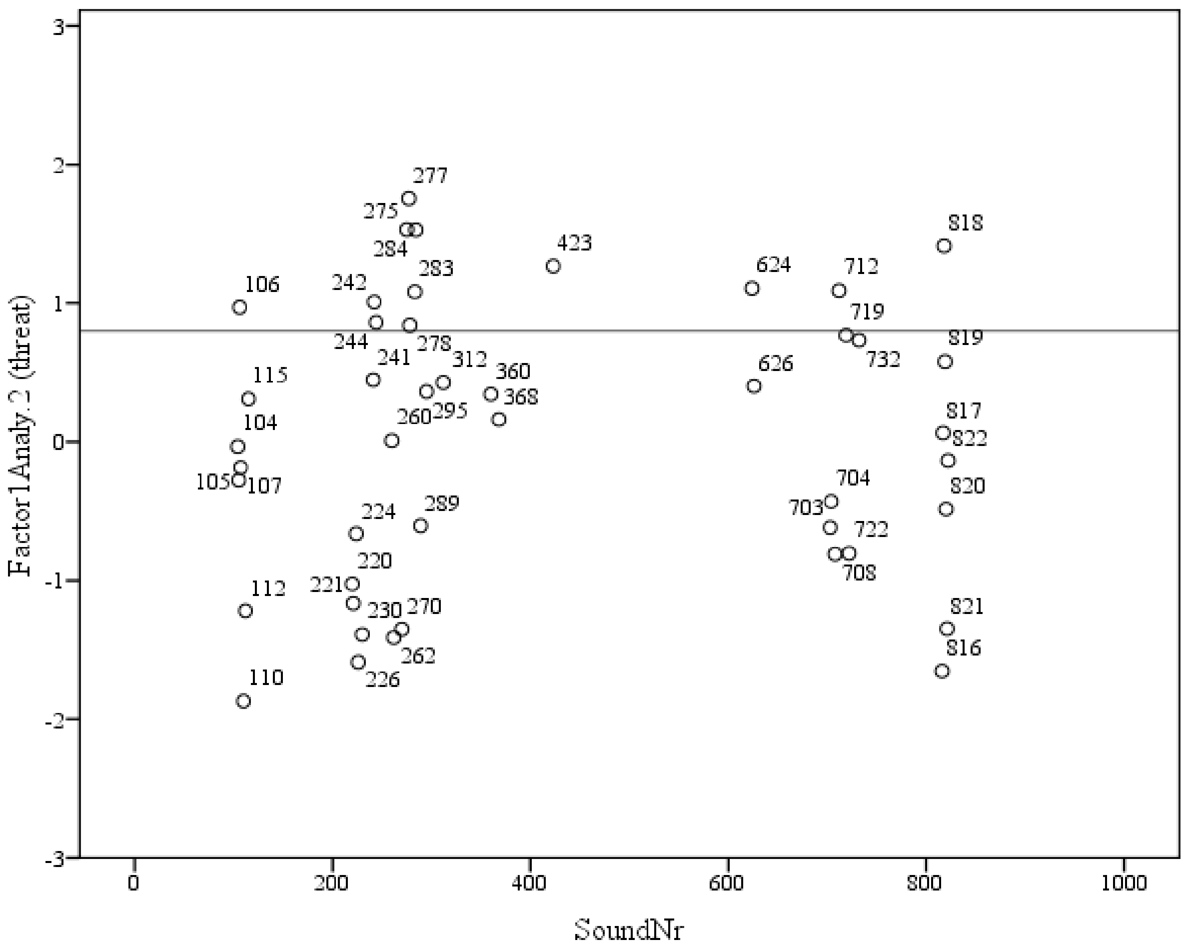


*Figure*4. The sound number was plotted against the ratings for the fourth factor (threat)

Note: The SoundNos. 106, 242, 244, 275, 277, 278, 283, 284, 423, 624, 712, 719 and 818 loaded positive on the first factor, with .8 or higher.

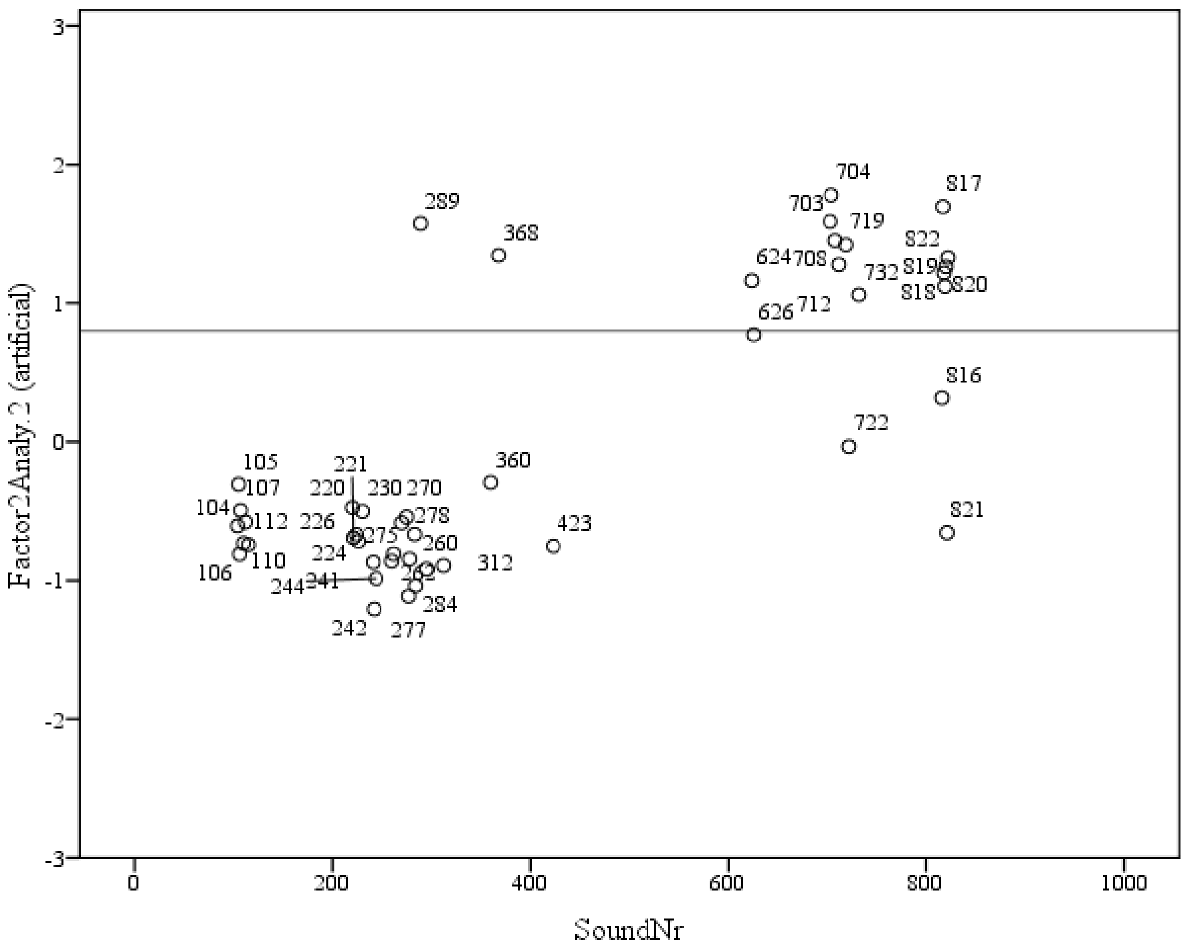


*Figure*5. The sound number was plotted against the ratings for the fifth factor (artificial).

Note: The SoundNos. 289, 368, 624, 703, 704, 708, 712, 719, 732, 817, 818, 819, 820 and 822 loaded positive on the first factor, with .8 or higher.

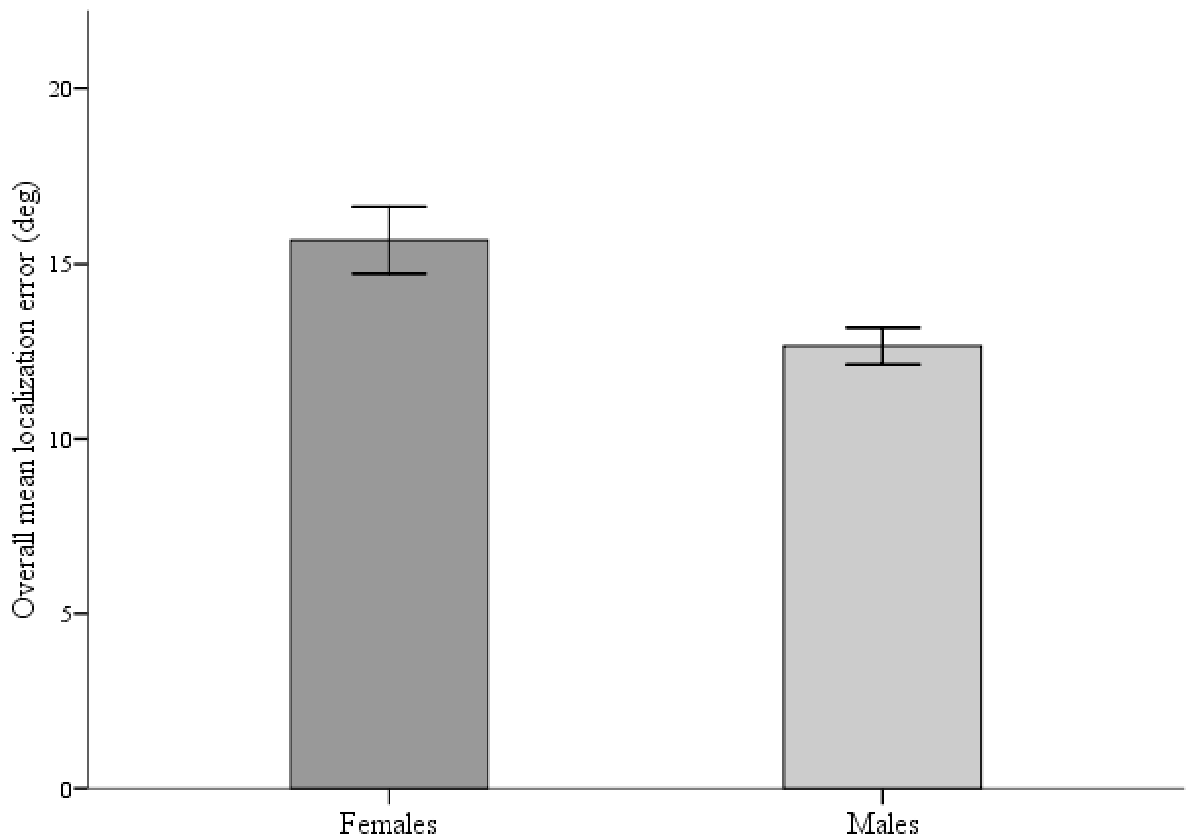


Figure6. Overall mean localization error of males and females for all 45 stimuli. *Note*: error bars (± S.E); Females (M=15.68); Males (M=12.64)

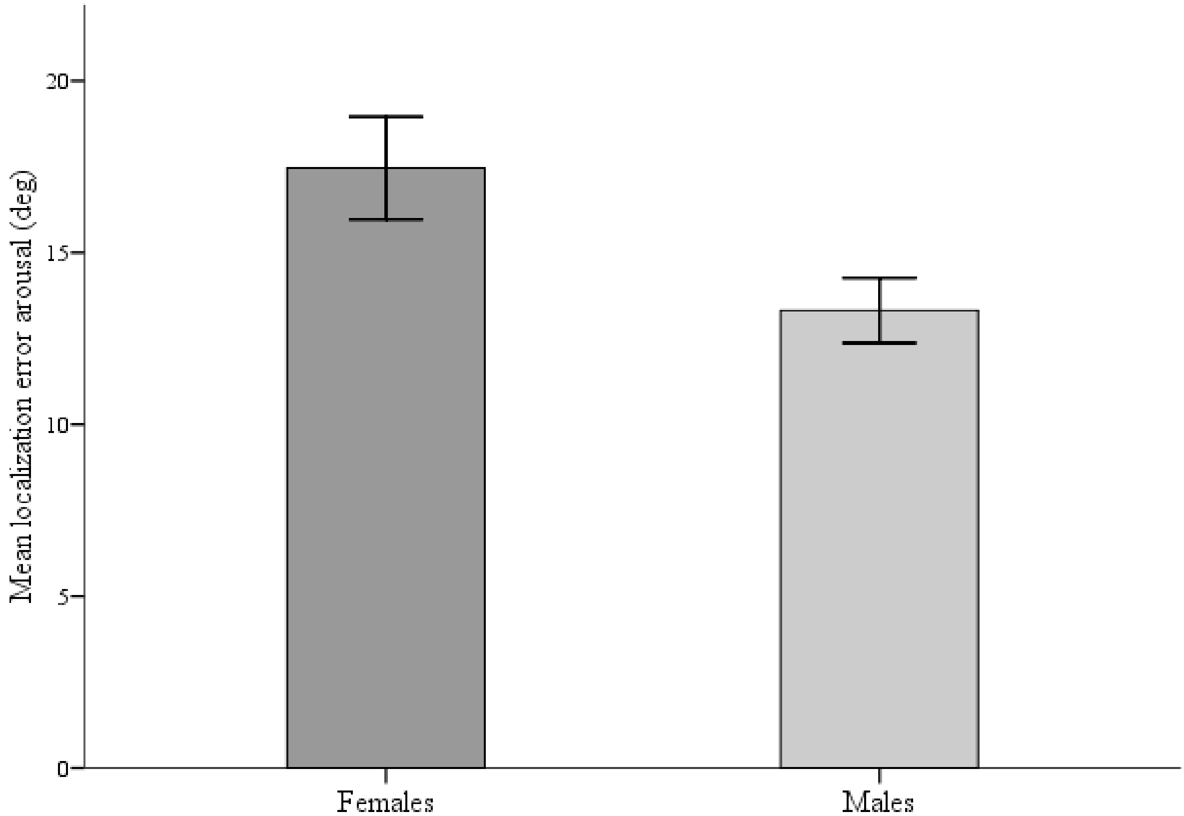


Figure7. Mean localization error for all arousing stimuli. *Note*: error bars (±S.E); Females (M=16.87); Males (M=12.13)

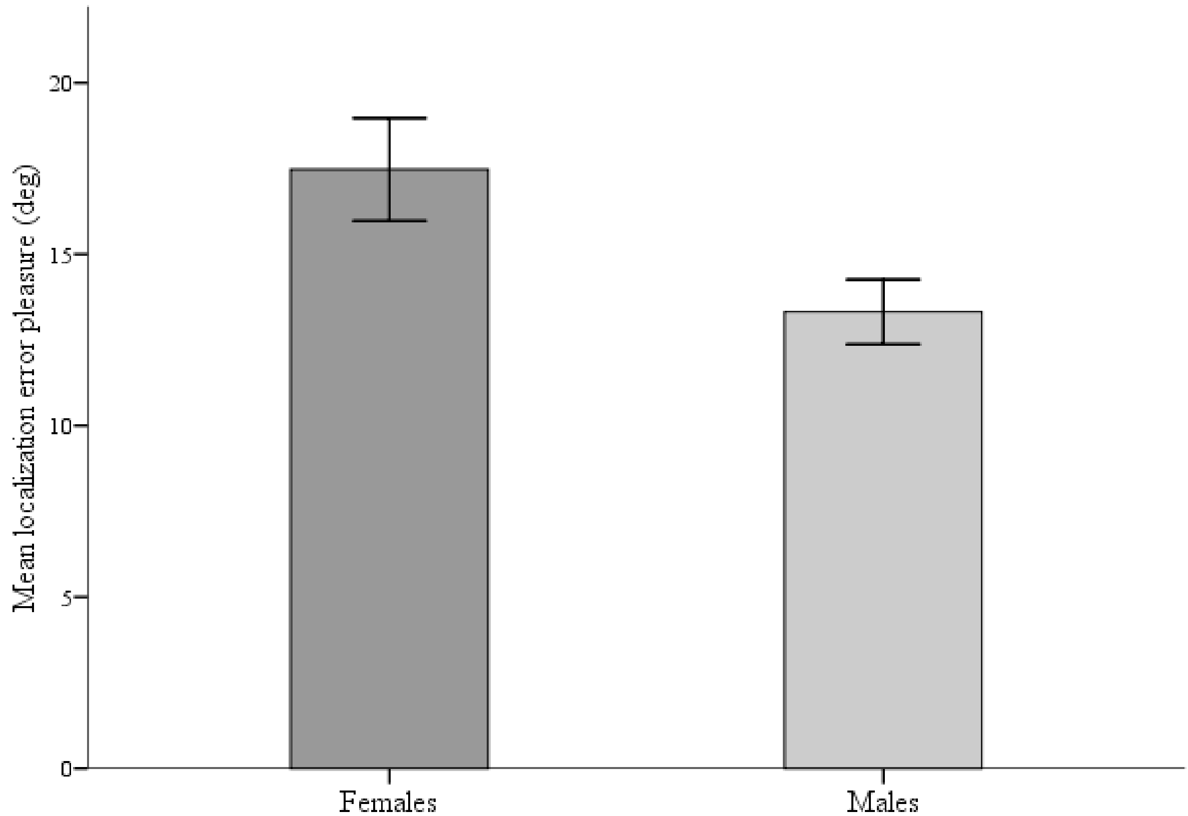


Figure8. Mean localization error for all pleasuring stimuli. *Note*: error bars (±S.E); Females (M=17.47); Males (M=13.31)

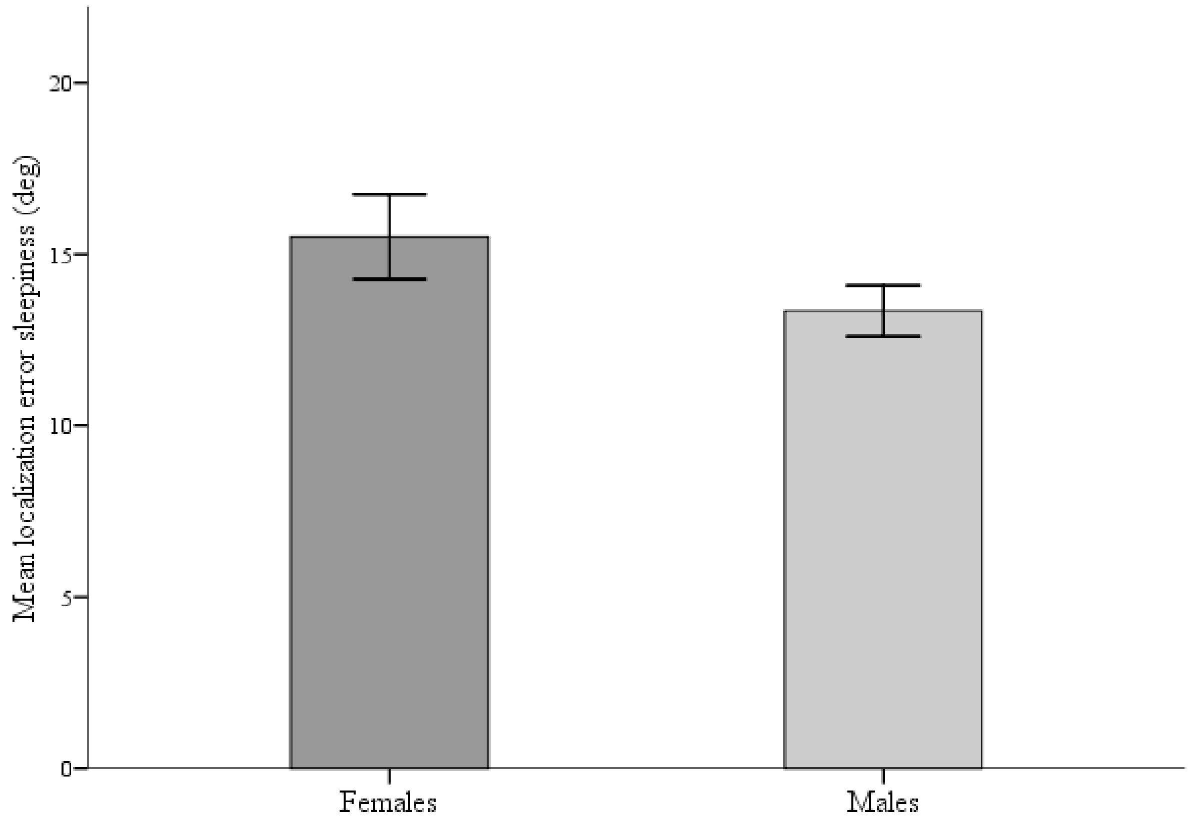


Figure9. Mean localization error for all sleepy stimuli. *Note*: error bars (±S.E); Females (M=15.50); Males (M=13.34)

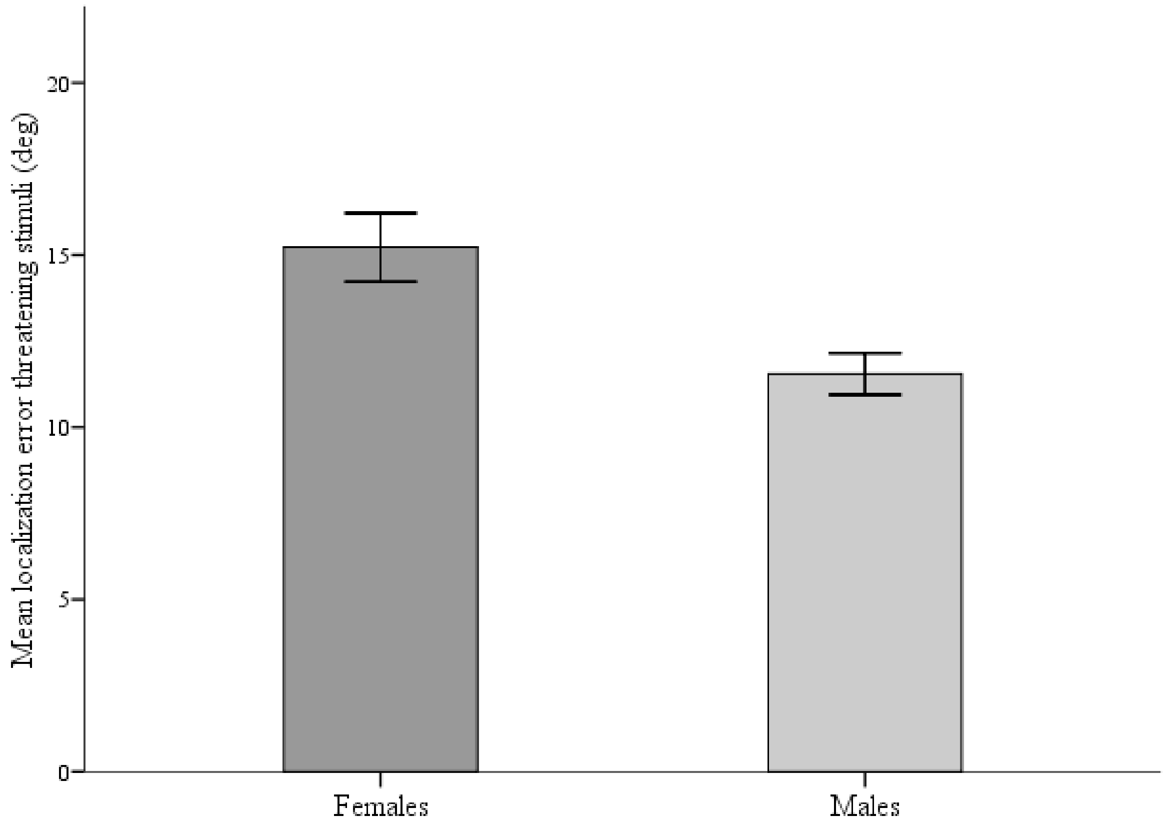


Figure10. Mean localization error for all threatening stimuli. *Note*: error bars (±S.E); Females (M=15.22); Males (M=11.55)

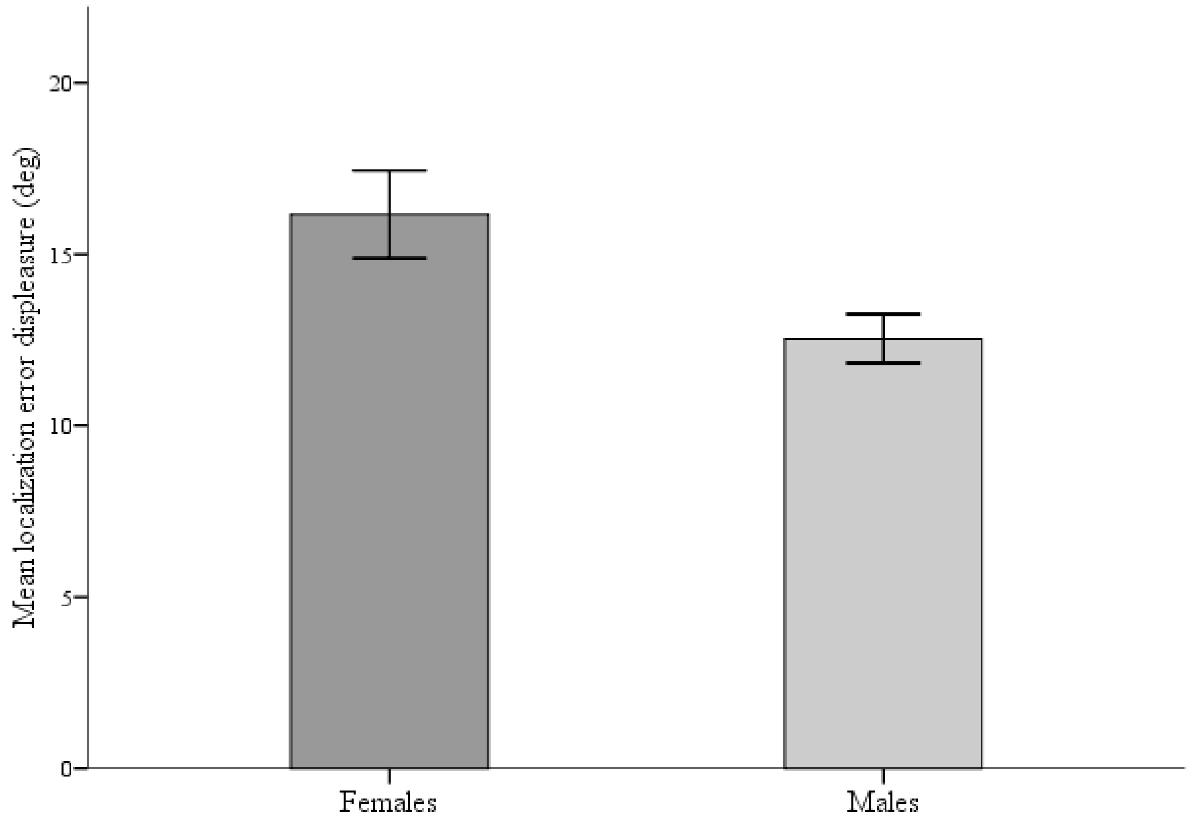


Figure11. Mean localization error for all displeasuring stimuli. *Note*: error bars (±S.E); Females (M=16.16); Males (M=12.52)

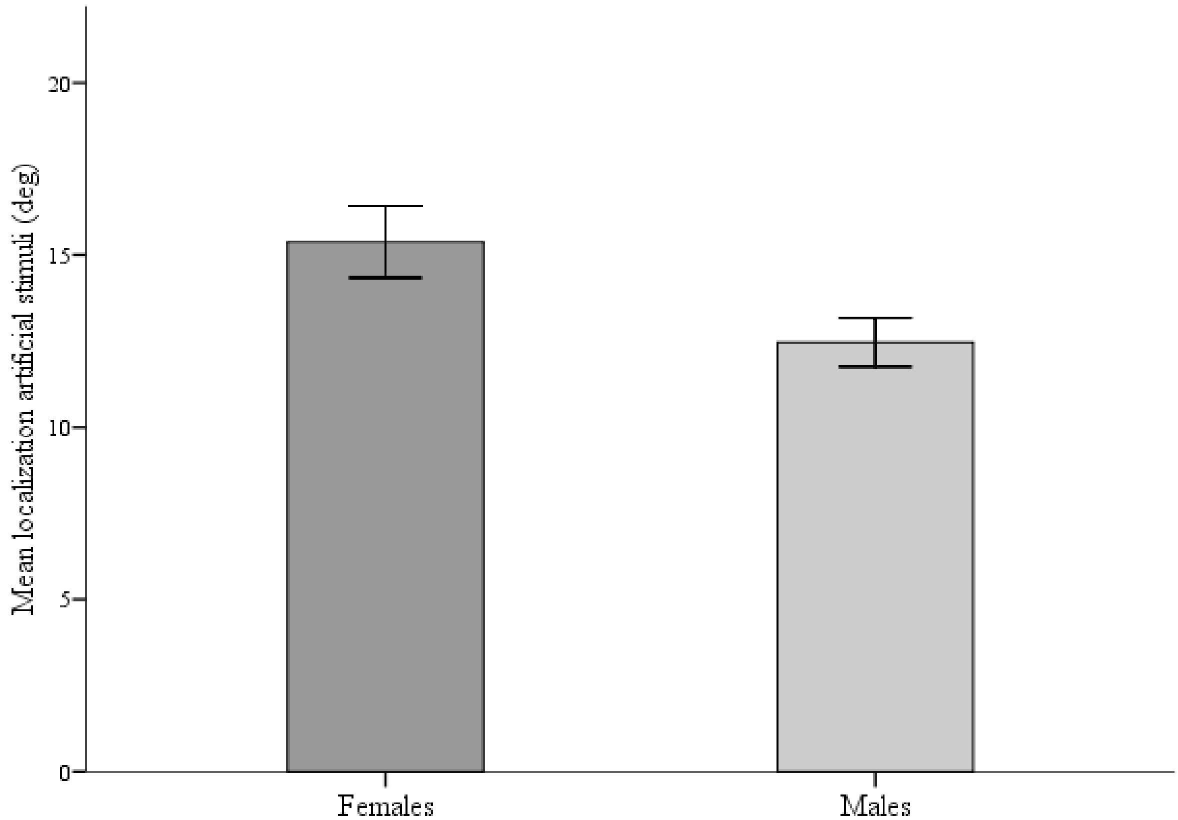


Figure12. Mean localization error for all artificial stimuli. *Note*: error bars (±S.E); Females (M=15.38); Males (M=12.46)

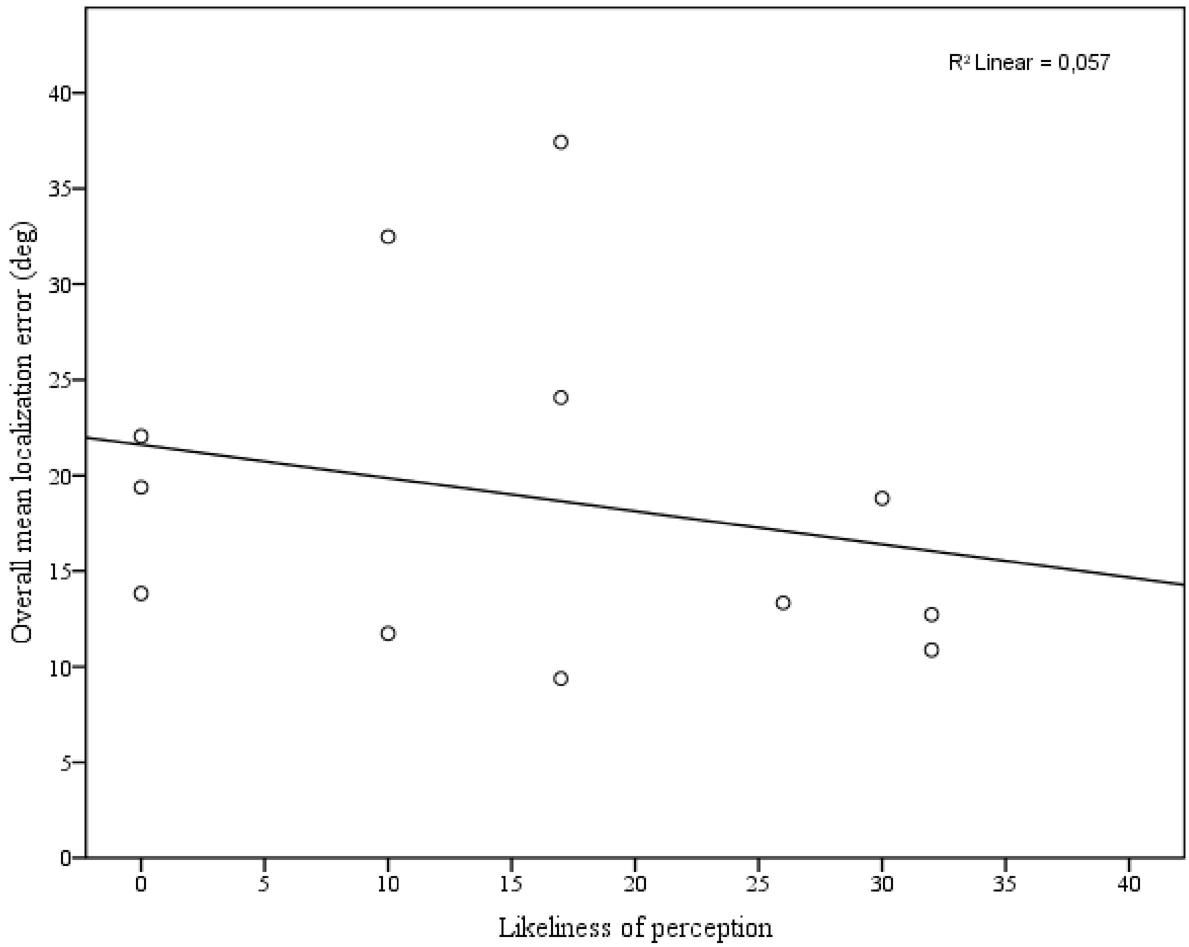


Figure13. Overall mean localization error (deg) plotted against likeliness of perception (percent).

Note: Dots representing the twelve females who didn't use hormonal contraceptives; R^2=0.057

Appendix A

Proband Nr.:
Alter:
Beruf:

Department of Anthropology
University of Vienna

universität wien

Fragebogen

Anmerkung: Bitte beantworten Sie die Ihnen gestellten Fragen gewissenhaft. Die erhobenen Daten werden streng vertraulich behandelt. Mit der Teilnahme an dem Versuch gestatten Sie dem Experimentator diese Daten für wissenschaftliche Analysen zu benutzen.

Ich habe den obigen Text gelesen und bin mit der anonymen Veröffentlichung meiner Daten einverstanden.

Wien, am

Unterschrift:_______________________

1. **Besteht eine ärztlich attestierte Beeinträchtigung Ihres Hörvermögens (Tinnitus, Taubheit,…)?**

   Ja □ Nein □
   Wenn ja, welcher Befund liegt vor?

2. **Hatten Sie jemals einen operativen Eingriff am Ohr?**

   Ja □ Nein □
   Wenn ja, an welchem der beiden Ohren?
   Rechts □ Links □ Beide □

3. **Benötigen Sie Hör-Hilfsmittel?**

   Ja □ Nein □
   Wenn ja, welches und auf welchem Ohr?

   Rechts □ Links □ Beide □ Hilfsmittel:

4. **Wie oft hören Sie laute Musik über Kopfhörer (Mp3 Player, etc.)?**

   selten (1/2mal/Monat) □ häufiger (1-2mal/Woche) □ täglich □

5. **Wie oft besuchen Sie laute Musikveranstaltungen (Clubs, Discos, Konzerte)?**

1-2 mal/Monat □ 3 mal oder öfter/Monat

6. Benutzen Sie einen Lärm- oder Schallschutz wenn die Musik laut ist?

Ja □ Nein □

7. Haben Sie Probleme Menschen in einem lauten Umfeld (z.B.: Party) zu verstehen?

Ja □ Nein □

8. Sind Sie Raucher/in

Ja □ Nein □

Wenn ja, wieviele Zigaretten rauchen Sie pro Tag?

9. Trinken Sie Alkohol?

Ja □ Nein □

Wenn ja, wie oft in der Woche?

10. Konsumieren Sie andere Drogen außer Alkohol und Tabak

Ja □ Nein □

Wenn ja, welche Droge/n und in welcher Häufigkeit?

Droge/n:

gelegentlich (1-2 mal im Monat) □ regelmäßig (1-2mal die Woche) □ täglich □

11. Stehen Sie zum jetzigen Zeitpunkt dieser Untersuchung unter dem Einfluss illegaler Rauschmittel/verordnungspflichtiger Medikamente?

Ja □ Nein □

12. Händigkeit

links □ rechts □ beidhändig □

13. Sind Sie Brillenträger/in oder tragen andere Sehbehelfe?

Ja □ Nein □

Wenn ja, welche Sehbehelfe?

14. Hatten Sie jemals eine gröbere Verletzung der Hände oder Arme (z.B.: Bruch)?

Ja □ Nein □

Wenn ja, welche Hand war betroffen?

links □ rechts □ beide □

15. **Haben Sie bereits an einem Hörexperiment teilgenommen?**

Ja □ Nein □

Wenn ja, an welcher Art von Experiment?

Nur von Frauen auszufüllen!

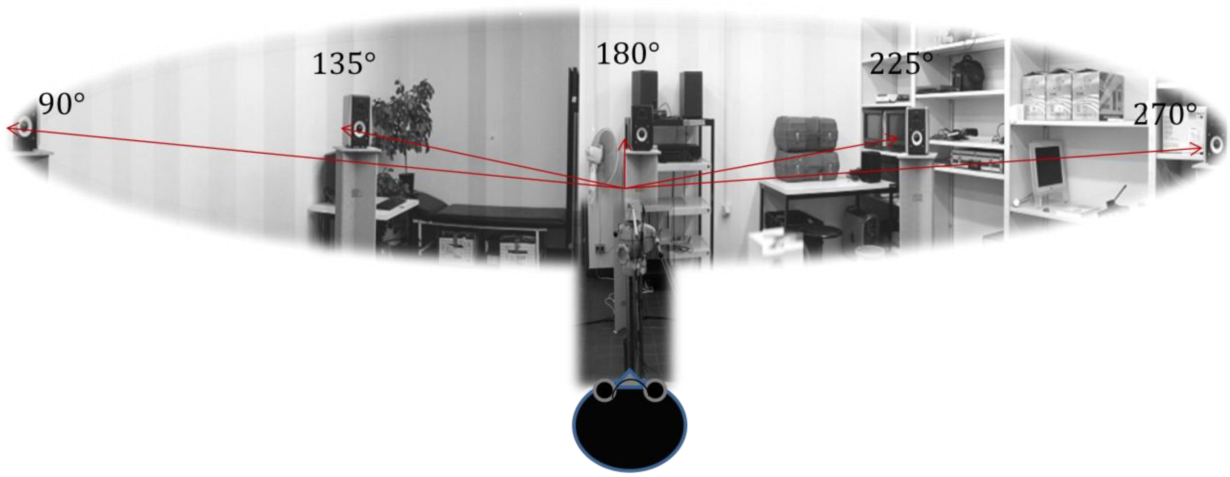
1. **An welchem Tag Ihres Zyklus befinden Sie sich?**

2. **Benutzen Sie zurzeit Verhütungsmittel?**

Ja □ Nein □

Wenn ja, welches und seit wann (Hormonpräparate, Spirale, etc…)?

Appendix B



This picture represents the experimental setup. *Note*: The numbers represent the position of the speakers in relation to the listener.

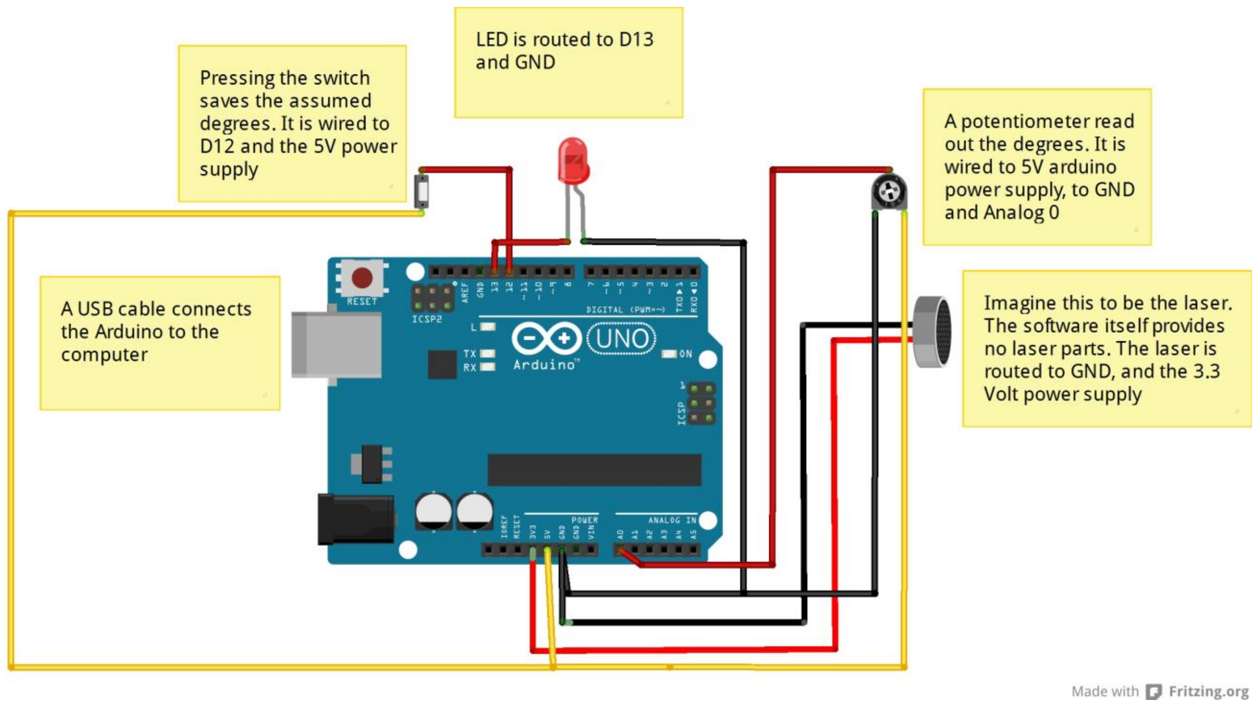
Appendix C

List of stimuli belonging to the 6 different categories

Note: Since the last 3 seconds of every stimulus were trimmed, the stimuli Gun Shot and Explosion didn't sound like the original sound. Because of this reason they were rated to belong to the category Sleepy.

Arousal	**Sleepy**	**Displ.**	**Threat**	**Artificial**	**Pleas.**
F.Cough	M.Cou	Panting	Growl	Gunshot	Baby
M.Whe	Yawn	Kids	F.Cough	Crowd	KidsTalk
B.Cry	**G.Shot**	M.Whe	Scream	Airraid	BoyLaugh
F.Scream	**Explosion**	Scream	F.Scream	B.Signal	MaleLaugh
C. Abuse	Clock	Rcoaster	Fight	Phone	KidsPlay
C.Sobb	Walking	Lighter	Attack	Clock	Giggling
Injury	Lighter	Candrop	Injury	Buzzer	Laughing
Attack	Bongos		Airraid	D.Drill	Whistling
Airraid			Buzzer	Crash	Guitar
B.Signal			M. Gun	Vibration	Hello
M.Gun				Gun2	

Appendix D



Note: This illustration shows the electronic scheme for the Hand Pointer Method.

Zusammenfassung

In der vorliegenden Studie wurde der Einfluss des Geschlechts auf mögliche Unterschiede in Bezug auf die Präzision der Lokalisation verschiedener ökologisch valider Geräuschstimuli untersucht. Um eventuelle Unterschiede zu testen wurde eine Umgebung mit fünf Lautsprechern, welche im Halbkreis angeordnet waren, und einer speziellen Handzeiger-Methode entwickelt. Die Stimuli wurden in sieben Sekunden Abständen randomisiert auf jeweils einem der fünf Lautsprecher abgespielt. Gleichzeitig ertönte aus allen fünf Lautsprechern eine Hintergrundsequenz einer belebten U-Bahn Station. Ziel der Probanden war es die plötzlich auftauchenden überlagerten Stimuli möglichst genau zu orten. Es wurde gezeigt, dass männliche Probanden im Durschnitt eine höhere Präzision in der Lokalisation der Stimuli hatten als weibliche Probanden. Um zu testen ob die Eigenschaften der Stimuli selbst für die Unterschiede in der Präzision der Lokalisierung verantwortlich waren, wurde zuvor eine Bewertungsstudie durchgeführt. In dieser konnten Probanden den Geräuschen verschiedene semantische Bedeutungen zuordnen. Bei Betrachtung des mittleren Fehlers der Abweichungen in Bezug auf die einzelnen Faktoren konnte gezeigt werden, dass männliche Probanden gefährliche, passive, und Geräusche mit einer negativen Valenz genauer orten als weibliche Probandinnen. Der angenommene Vorteil für Probandinnen in Bezug auf die Präzision der Ortung von Stimuli mit einer positiven Valenz konnte nicht gezeigt werden. Diese Ergebnisse zeigen einen klaren Vorteil für Männer in der Richtungslokalisation von überlagerten Stimuli im Raum, und lassen darauf schließen, dass es kognitive Geschlechterdifferenzen in Bezug auf die Richtungslokalisation von Geräuschen gibt. Da männliche Probanden ebenfalls genauer bei Tests auf visuell-räumlichen Fähigkeiten abschnitten, ist dieser Vorteil möglicherweise auf Geschlechtsunterschiede in den Verschaltungen zwischen visuellen und auditiven Arealen im Gehirn zurückzuführen.

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