SIC – Sound Illusion Cube

Thijs Eerens
info@thijseerens.com

Media Technology MSc Program, Leiden University, the Netherlands

(Reading this paper may influence the experience of SIC)

Abstract:
SIC is an installation built to test if people get spatially disorientated by using spatialized moving sound in combination with physical movement of the body. It is based on the madhouse principle in fun parks but in stead of people seeing a rotating room, they now hear rotating sound while they are blindfolded sitting in a moving chair. According to the test results, SIC is working and so people can get spatially disoriented by sound and movement. This paper will present the research methods and will mention what can be improved and what can be done with this type of disorientation.

1. Introduction
Optical illusions are a well-known phenomenon to us. We know Escher because of his “strange” paintings and everybody knows pictures like the following:

Fig 1: Two examples of optical illusions

In fun parks such as “Disney World”, “Walibi World” or “De Efteling” optical illusions are often used to disorientate and thus entertain people (e.g. Madhouses and Haunted Houses).

If you google for “optical illusions” you will find approximately 1.250.000 hits. But if you google for “auditory illusions”, how ever, you will find less than 17.200 hits.

Apparently, “auditory illusions” is not a commonly used term.

2. SIC – Sound Illusion Cube
SIC is an installation used to research the possibility of getting spatially disorientated by using only sound and movement. It is based on the Madhouses in fun parks, where people are being spatially disorientated by sight and movement for entertainment.

Since the experiments have proven that SIC works, it will be possible to integrate this phenomenon in new amusement park attractions so that visitors can experience a new sensation.

2.1 Madhouse
A madhouse is a rare type of attraction known as a 'haunted swing' or 'madhouse’, which is a sort of haunted house, in which the visitors get the illusion that either the house, the visitors themselves or both are turned upside down.

The benches on which the visitors are seated are placed on a swing that swings with a maximum angle of 30 degrees. The interior of the house consists of a drum built around this swing that can turn 360 degrees, giving the visitors the illusion that they are turned upside down; they get spatially disorientated.

2.2 What is SIC exactly?
SIC is a big black cube. Speakers are placed in every corner of this cube, pointing at the center of the cube. (fig. 2)
Because of the positions of the eight speakers it is possible to simulate a sound source coming from any location outside the cube. A chair is placed at the center of the cube. The chair can lean over to the left, to the right, to the front and to the back. Seatbelts are present so the person in the chair cannot fall out of it. Inside the cube there is total darkness and the person in the cube is blindfolded. He only hears the sound coming out of the speakers.

3. Spatial Disorientated and illusions

3.1 Spatial Disorientation
Spatial disorientation is a condition in which someone’s perception of direction (proprioception) does not correspond with reality. It can be caused by disturbances to or defects in the vestibular system, it is more typically a temporary condition.

3.2 What is an Illusion?
An illusion is a distortion of a sensory perception, revealing how the brain normally organizes and interprets sensory stimulation. Although illusions distort reality, they are generally shared by most people. Illusions can occur with any of the human senses, but visual illusions are the best-known and best understood. This can be explained by the fact that the visual sense often dominates the other senses. For example, individuals watching a ventriloquist actually believe that the voice is coming from the dummy because they are able to see the dummy pronounce the words. Some illusions are based on general assumptions made by our brains during perception. These assumptions are made using organizational principles, like Gestalt; an individual’s ability of depth perception and motion perception, and perceptual constancy. Other illusions occur because of biological sensory structures within the human body or conditions outside of the body within one’s physical environment.

3.2.1 Optical Illusion
An optical illusion is characterized by visually perceived images that, at least in common sense terms, are deceptive or misleading. Thus, the information received by the eye is processed by the brain which then produces, on the face of it, a percept that does not correspond to a physical measurement of the stimulus source. A conventional assumption is that there are physiological illusions that occur naturally and cognitive illusions that can be demonstrated by specific visual tricks that say something more basic about how human perceptual systems work.

3.2.2 Auditory Illusion
An auditory illusion is an illusion of hearing, the sound equivalent of an optical illusion: The listener either hears sounds that are not present in the stimulus, or he hears “impossible” sounds. In short, audio illusions highlight areas where the human ear and brain, as organic, makeshift tools, differ from perfect audio receptors. An example of an auditory illusion is the “Shepard tone”. It is a sound consisting of a superposition of sine waves separated by octaves. When played with the base pitch of the tone moving upwards or downwards, it is referred to as the Shepard scale. This creates the auditory illusion of a tone that continually ascends or descends in pitch, yet which ultimately seems to get no higher or lower.

4. Spatial Sound

4.1 Hearing spatial sound
Humans are normally able to hear a variety of sound frequencies, from about 20 Hz to 20 kHz. The ability to judge just where the sound is coming from, sound localization, is dependent on both hearing ability of each of the two ears, and the exact quality of the sound. Since each ear is located on an opposite side of the head, a sound will reach the closest ear first, and its amplitude will be larger in that ear. The shape of the pinna (outer ear) and of the head itself results in frequency-dependent variation in the amount of attenuation that a sound receives as it travels from the sound source to the ear: Furthermore, this variation depends not only on the azimuthal angle of the source, but also on its elevation. This variation is described as the head-related transfer
function, or HRTF. As a result, humans can locate sound both in azimuth and altitude. Most of the brain's ability to localize sound depends on interaural (between ears) intensity differences and interaural temporal or phase differences. In addition, humans can also estimate the distance that a sound comes from, based primarily on how reflections in the environment modify the sound, for example as in room reverberation.

4.2 Research in spatial hearing and audio-induced illusory self-motion
There has been, and still is a lot of research going on in spatial hearing and audio-induced illusory self-motion. Not to disorientate people but to research the boundaries of the human senses. In the search for comparable researches there could not be found one which use spatial sound and body tilt in the same experiment. It seems it never has been researched before. However, other interesting research has been done that might be useful in some way. Two examples of this research are mentioned below.

How we localize sound
In fig. 3 the installation is shown W. M. Hartmann used to do his research.[7]

The sound localization facility at Wright Patterson Air Force Base in Dayton, Ohio, is a geodesic sphere, nearly 5m in diameter, housing an array of 277 loudspeakers. Each speaker has a dedicated power amplifier, and the switching logic allows the simultaneous use of as many as 15 sources. The array is enclosed in a 6m cubical anechoic room: Foam wedges 1.2m long on the walls of the room make the room strongly absorbing for wavelengths longer than 5 m, or frequencies above 70 Hz. Listeners in localization experiments indicate perceived source directions by placing an electromagnetic stylus on a small globe.

The effect of body tilt on neural responses in monkey inferior
In fig.4 the installation John van Opstal used to do his research, is shown.[8] It examines the effect of body tilt on neural responses in monkey inferior colliculus. The installation consists of a chair that can make whole-body rotations around two independent (horizontal and vertical) axes. The axes are controlled by Harmonic Drive systems.

4.3 Combining sphere and chair
By combining the previous two research installations SIC arises. With the geodesic
sphere from W.M. Hartmann it is possible to very precise place sound in a 3D-environment. And with the Two-axis vestibular primate chair from J. van Opstal it is possible to rotate the test person in every desired position.

5. Research elaboration
To research if it is possible to disorientate people using SIC, tests were done. All tests are based on the same principle, namely changing the tilt angle between the chair and the sound. Afterwards the test persons were asked what they felt during the test.

5.1 Tilting the chair
Two electro motors are able to tilt the chair in every direction. The maximum tilt angle is approximately 30 degrees. The speed of the tilt movement is adjustable. Because of this it is possible to start or stop the movement very gradually, so the test person won’t notice it.

5.2 Moving the sound
In SIC, eight speakers are positioned in every corner of the cube. To create spatial audio the Ambisonic technique is used. With Ambisonic it is not only possible to pan Ambisonic recordings, but it is also possible to spatially pan a stereo sound over the eight speakers. In the case of SIC stereo sound is being spatialised.

6. Test results
To see if different types of music have any affect on the experience of the test person, different types of sounds are used during the tests. There are many different types of sounds (e.g. stereo music, human voice, ambisonic recordings, etc.). To research whether the type of sound is of any influence, tests with test persons were done. Most of the test persons knew nothing or very little about the research.

6.1 Test with stereo music
The test persons entered SIC blindfolded and were told they were going to do two tests. Afterwards they had to answer some questions. The order of the tests was random.

In test 1 the sound moves together with the chair (fig. 5), and in test 2 the sound moves in the exact opposite direction of the chair. In both tests the movement of the chair is exactly the same. In test 1 the difference in angle between the chair and the sound is zero degrees since the sound moves in the same direction as the chair. In test 2 there is a difference between the angle of the chair and the sound. For example if the chair tilts 10 degrees to the left, then the sound rotates 10 degrees to the right, in this case the test person will notice a difference in angle between the sound and the chair of 20 degrees. With this scenario in test 1, the test person will notice a difference in angle between the sound and the chair of 0 degrees.

Because the movement of the chair is the same in test 1 as in 2, only the sound could affect the experience of the test person. When the test persons had finished the two tests they were asked if they felt any difference between test 1 and 2. In almost every case the test person declared that in test 2 the tilt angle of the chair in every direction was larger than in test 1. This was an illusion, because the chair had moved in exactly the same way.

6.2 Test with human voice
People are good in localizing human voices; we are trained to do that from our birth. The better the sound can be located, the better it can be used to disorientate people. But when recordings with only human voices are used, people would hear the motors of the chair since people use pauses in their conversations and have to take a breath. Due to these pauses the current realisation of SIC cannot be used to research this type of sounds because the
people will hear the motors and realizes the chair is moving.

6.3 Test with ambisonic recordings
When first- or second-order Ambisonic recordings are played back on SIC it is possible to create spatial sound environments. If the recording is right, the played back sound will sound just like it had sounded when it was recorded. Using this technique, it is possible to create a 3d environment around the test person (e.g. car driving from left to right, people walking by, high above an airplane is flying over etc.) Rotating this 3d environment has also been tested. The ambisonic recordings that were needed to do the tests have to describe many constant moving sound sources, for instance recordings of a busy crossroad where cars come and go all the time. Recordings with no such constant movement, for instance children on a playground or sounds of a busy market, are very hectic and therefore useless since people are not able to hear the rotation of these sounds since the sounds are coming from all directions. Since there were no ambisonic recordings which describe these constant movements of sound sources, tests with ambisonic recordings could not be done.

6.4 Test with different types of music
There are many different types of music. Some music is very relaxing and smooth, other music is very powerful and ‘aggressive’. Tests with these different sounds have been done. When people hear smooth relaxing (lounge) music, they experience the movement of the chair as gently or smooth. It is as if they are being rocked asleep. When people hear more active and aggressive music, they experience the same movement of the chair as scary or dangerous. They get the feeling they could be thrown out of the chair at any moment.

7. To consider
7.1 People do reason
Because people are much more visually oriented, it is hard to trick or fool them by sound instead of images. Therefore it is necessary to eliminate extra stimuli while trying to disorientate people by sound. The blindfold prevents people from seeing the chair and its surroundings.

Than there is another problem. When the chair smoothly stops tilting, it is possible to give the person in the chair the idea he is tilting further by letting the sound rotate further. But the motors of the chair cause vibrations. The person in the chair feels these vibrations and knows there is “something” happening. Since the person in the chair will notice the stopping of the chair, because it is not vibrating any more, the person realizes he’s being tricked. Due to this shortcoming is not possible to use SIC to disorientate people in this way.

7.2. Some sounds don’t work
The type of sound which is played will also influence people’s experience. When the sound of a bird or a mosquito is moving around a person’s head, it is not a very unusual thing and people accept this. But when a class of school children, a big truck or a complete symphonic Orchestra is moving around a person’s head it is different. In this case a person cannot except till some point this orchestra is moving around him, so the test person will think he is moving around the orchestra.

7.3. Rotation border for sound
The rotation angle of the sound must not be too big compared to the tilt angle of the chair. If the tilt angle is much bigger than the tilt angle of the chair, it does not match with the test person’s feelings anymore. For example, if the test person hears the sound upside down, but he does not feel he’s falling out of the chair, his tactile sensory will ‘win’. Which means the person concludes that the music is upside down instead of himself.

8. Things to improve
SIC is a low budged installation, the motors used to move the chair are not strong enough. The speakers and amplifiers should be identical, but instead 4*2 different speakers and 4 different
amplifiers are used. To create a spatial sound, 8 speakers are a minimum, more speakers will improve the quality of the spatial sound.
The walls of the cube should absorb all sounds coming out of the speakers to minimize reflection, and block the sounds from outside the cube from coming in. Inside the cube it should be completely dark, so a blindfold should not be necessary. Improving these problems will improve the degree of disorientation.

9. More research questions
This research was to prove that people using SIC could or could not be disorientated. But there are many other thinkable interesting research topics concerning this project. For instance, how do blind people react on SIC and which movement of the chair and sound is the most disorientated one? How would people experience an installation like SIC which does not have any shortcomings? (e.g. Hydraulic cylinders, more and better speakers, etc.) Will other movements like rotating or lifting the chair increase the amount of disorientation? What will the effect be when good ambisonic recordings can be used?

10. The Final “ride”
The results of the tests are used to make a final ride. In this final ride the different ways to disorientate people which were tested are combined. Also drama is added to make the show complete.

11. Conclusions
Despite the shortcomings of SIC the conclusion can be drawn that people get disorientated by spatialized sound and body movement. Not only the movement of the sound in combination with the chair has effect on the degree of disorientation, also the type of music will influence the degree in which you get disorientated.

There are two ways of disorientating people. In one way people will notice their disorientation during the test, and in the other way people do not notice it.
In the test where sound moves together with the chair, test persons notice there is something happening but do not know exactly what it is, since the sound has not moved according to their perception. The test persons felt disorientated during the “ride”.
In the test where the sound is moving in the opposite direction as the chair does, the test persons feel there is something happening, and the sound confirms this feeling, namely their tilting. After the test the test persons claimed they tilted further during this test as during the other test. This is not true, so the test persons where disorientated without their notice.

Compared to optical disorientation, it is hard to disorientate people by sound. The installation used to disorientate people by sound has to meet a couple of conditions. The movement of the chair has to be quiet, smooth and the motors have to be strong enough. Moving the chair should not cause vibrations that can be felt by the person in the chair.
The more speakers used, the better spatial sound is hear able.
The test person should be blindfolded or the room should be completely dark. And he or she should hear nothing else then the sound of the installation.

Acknowledgements
I would like to thank Edwin van der Heide for his support as a supervisor. I also would like to thank Michel Buijs (Café/restaurant Havana Utrecht) for the space and materials to do my research. Other people whom I would like to thank are Hester Kloosterboer, Wim Bles, Peter Clercks, John van Opstal, Lex van den Broek and all the test persons and people who helped me.

References
7. W. M. Hartmann, How we localize sound (1999)
8. J. van Opstal, http://www.mbfys.ru.nl/~johnvo/projects03.htm#project16
Appendix 1:

Schematical drawing of SIC

**SIC – Sound Illusion Cube**

- **PC**
  - MaxMSP
  - PatchMix DSP
  - Outputs a tilt angle from x- and y-axe
- **ADXL Tilt sensor**
  - Analog input
- **Wiringboard**
  - PWM signal
  - Speed controller
  - 36V DC
- **Speed controller**
  - 36V DC
  - M1 Left / Right
  - M2 Front / Rear
- **EMU 1820 Sound card**
  - 8 channel output
- **Amplifier 1**, **Amplifier 2**, **Amplifier 3**, **Amplifier 4**
  - 8 speakers, one in every corner of the cube
- **8 speakers, one in every corner of the cube**

**SIC – Sound Illusion Cube**

- **8 speakers, one in every corner of the cube**
- **8 channel output**
- **36V DC**
- **Left / Right**
- **Front / Rear**

**EMU 1820 Sound card**

**Amplifier 1**, **Amplifier 2**, **Amplifier 3**, **Amplifier 4**

**8 speakers, one in every corner of the cube**

**36V DC**

**Left / Right**

**Front / Rear**