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Sensation and Perception The Staircase Procedure for Finding a Perceptual Threshold

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The Staircase Procedure for Finding a Perceptual Threshold

Overview

Psychophysics is the name for a set of methods in perceptual psychology designed in order to relate the actual intensity of stimuli to their perceptual intensity. One important aspect of psychophysics involves the measurement of perceptual thresholds: How bright does a light need to be for a person to be able to detect it? How little pressure applied to the skin is detectable? How soft can a sound be and still be heard? Put another way, what are the smallest amounts of stimulation that humans can sense? The staircase procedure is an efficient technique for identifying a person's perceptual threshold.

This video will demonstrate standard methods for applying the staircase procedure in order to identify a person's auditory threshold, that is, the minimal volume necessary for a tone to be perceived.

Procedure

1. **Stimuli and Equipment**

    1.1. This experiment will require a computer with basic experimental software as well as a set of headphones and a relatively quiet testing room (sound proofing is not necessary).

    1.2. The stimuli in the experiment will be tones of with frequencies of 1 kHz, 2 kHz, 3 kHz, 4 kHz, 5 kHz and 6 kHz. Human hearing is best within this frequency range.

    1.3. During the course of the experiment, the volume of the tones will be varied adaptively in the range of 1 to 40 dB ~~(Decibels)~~, as will be clear in the context of the experimental design, in order to measure the minimal perceivable volume at each of the six frequencies.

2. **Design**

    2.1. The experiment will involve six blocks, one for each of the six frequencies. This is because human thresholds are not the same for all frequencies. In other words, the threshold will be measured independently for each of the six frequencies. The following design will thus produce six testing programs.

    2.2. Program the experiment to present a given frequency during each trial.

2.2.1. In each trial, the participant's task will be to report whether or not she heard the tone presented. Use the 'Y' key to indicate 'Yes' responses, and the 'N' key to indicate 'No' responses.

2.2.2. The experiment will always begin with a very low volume tone—one that the participant should not perceive. Program the first tone to have a volume of 2 dB played for 200 ms.

2.2.3. Whenever a 'Yes' response is produced, the volume in the next trial will be lowered by one step, and whenever a 'No' Response is produced, it will be increased by one step. It is thus possible to visualize the experimental design as a flow chart, as shown in **Figure 1**. Tones will always be played for a duration of 200 ms each.

2.2.4. Include 30 trials in the experiment.

2.2.5. To keep the participant visually engaged, ~~the screen can~~ display the words 'Yes or No?' on the screen after each tone is played.

2.2.6. Generate six experimental programs like this, one for each of the six frequencies between 1 and 6 kHz.

2.2.7. Be sure the program outputs the volume of the tone presented on each trial, and the response the participant supplied.

3. Procedure

~~3.~~

3.1. Note that one can easily test him or herself.

3.2. Before the participant puts on the headphones, explain the instructions as follows:

3.2.1. "This experiment is designed to measure your auditory threshold, the softest or quietest sound you can perceive. In each trial, the computer will play a tone through the headphones, and all you need to do is press the 'Y' key if you heard the tone, or the 'N' key if you did not. It is okay to press the 'N' key. Some of the tones will be very soft, and we do not expect you to always hear them. Just reply honestly, and do your best. The experiment includes six blocks with 30 trials each. All six blocks should only take about 10 minutes, including breaks in between."

3.3. When the participant is ready, launch the first program, the one for the 1 kHz tone.

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3.4. You may leave the room while the participant completes the program. Shut the door if possible to minimize external noise.

3.5. After the first experiment is complete, ask the participant if she has any questions. Let her take a break for ~~one to two minutes~~1-2 min, removing the headphones during this time.

3.6. Now run the program for the 2 kHz tones.

3.7. And then repeat 3.4~~—~~–3.6 until all six tones have been tested.

4. Analyzing the results

4.1. To a~~A~~nalyz~~s~~e the results, make a separate table for each of the six experiments.

4.2. The table is the raw output from the experimental program. It should include the trial number, the volume of the tone presented, and the response the participant supplied. **Figure 2** shows what a portion of the table will look like for the first 10 trials with a tone of 1 kHz~~Z~~.

4.3. Check to make sure that your program worked properly~~—~~—*i.e.*, that 'Yes' responses led to a decrease in volume, and that No responses produced increases in volume.

4.4. Now, make a graph: T~~t~~he X-axis should be the trial number, and the Y-axis should plot the *volume* of the tone presented on that trial. **Figure 3** shows an example.

4.5. Generate a graph like this for each tone.

4.6. Now average together the volumes played during the last ten trials of the experiment for each tone. The value obtained is called the 'volume threshold.'

~~**4.5.**~~**4.7.** Figure 4 is an example of the volume threshold as a function of pitch.

Representative Results

The aim of the staircase procedure is to bring the participant to a volume at which they can just barely hear a tone. This is achieved by prompting a series of 'No' responses in the first few trials. Once a 'Yes' response is produced, the goal is to keep the volume played close to the one that elicited the first 'Yes'. This is done by lowering the volume whenever a 'Yes' response is given. This produces a pattern in which the volume rises steadily in the first few trials, and then

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With results obtained for six tones of different frequencies, one can see that perceptibility thresholds vary by frequency (what is often called~~,~~ pitch). Higher pitched sounds are harder to hear than lower pitched ones. To see this graphically, ~~compute~~ plot the volume threshold for each of the six tones tested in the experiment, just as done for the 1 kHz tone ~~— by averaging the volumes played during the last ten trials of each individual experiment.~~as shown in **Figure 4** ~~shows such a graph~~. The data shown are for a single participant, 20 years old. The main pattern is that the low frequency tones are easier to hear than high frequency tones. This is a fact of human hearing that arises because of the structure of the auditory system, starting with nature of the vibrating filaments and bones inside the human ear.

Indeed, as people age, the disparity between low and high frequency sounds increases. **Figure 5** g~~G~~raphs auditory thresholds for the 20-year-old subject shown in **Figure 4**, along with thresholds for a 40-year-old and a 60-year-old. In general, thresholds increase as people get older. But in addition, higher frequency tones become considerably harder to hear than low frequency tones.

Applications

One of the primary applications of the auditory staircase procedure is to assess hearing impairment. Beyond normal aging, hearing impairments can be caused by damage to the inner ear, brain damage, and disease. Often, hearing impairment affects particular frequencies more than others. The staircase method can be used to determine whether someone possesses especially poor hearing within a narrow frequency range, which would suggest hearing impairment caused by more than normal aging. **Figure 6** graphs auditory thresholds for a hearing impaired 60-year-old compared with an unimpaired 60-year-old. The impaired individual suffers hearing loss at 4 and 5 kHz, as indicated by very high auditory thresholds at those frequencies. Otherwise, the impaired individual performs similarly to an age matched control.

This approach can also be used to assess the consequences of various types of experiences on the auditory system. For example, studies have used a threshold approach to evaluate the effects of hearing loud heavy-metal music in a concert. Scientists tested people just before attending a concert, and a half an hour after. Perhaps unsurprisingly, heavy metal increased the volume threshold for sounds, especially in the range of 6Hz. Rock music can make you hard of hearing!

(Drake-Lee, A. B. (1992). Beyond music: auditory temporary threshold shift in rock musicians after a heavy metal concert. *Journal of the royal society of medicine*, *85*(10), 617-619.)

Figures

Figure 1. **A flow chart for the design of an experiment using the auditory staircase procedure.** The first trial always involves a tone played at an inaudible volume of 2 dB. Because the participant should not detect that tone, a 'No' response will be given, and the volume in the next trial will be increased by 1 dB (to 3 dB). Every trial (including and) following the second

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Commented [JS3]: Can this difference point to the localization of damage, *i.e.*, auditory cortex rather than the inner ear?

No it could have to do with deterioration of parts of the inner ear with different sensitivities.

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proceeds with the same directive: If a ‘Yes’ response is supplied by the participant, the volume in the next trial is reduced by 1 dB. And if a ‘No’ response is supplied, the volume in the next trial is increased by 1 dB. An experiment will include 30 trials per frequency.

Figure 2. A sample of a table that includes the required outputs from an auditory staircase experiment. Note that data reported are for a single subject (labeled Subject #1) and for a single frequency (1000 Hz). The table includes three columns: the trial number, the volume of the tone presented on that trial (in dB) and the response given by the participant.

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Figure 3. Sample results from a single participant and with a single tone. The graph plots the volume of the tone played, in ~~Decibels (~~dB~~)~~, as a function of the trial number for each of the 30 trials. The main pattern is that the participant cannot hear any tone in the first few trials, producing a series of ‘No’ responses and prompting volume increases until the auditory threshold is reached. At that point, the participant moves back and forth between ‘No’ and ‘Yes’ responses allowing the researcher to identify the place at which sounds first become detectable.

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Figure 4. Volume threshold as a function of frequency. Data shown are for a single participant, age 20 yrs. Because of the structure of the human auditory system, sounds with lower frequencies—what are colloquially called lower pitched or deeper—are easier to hear than high frequency (high-pitched) sounds. It takes a larger volume to make a high frequency sound audible.

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Figure 5. Volume thresholds as a function of frequency and age. In general, volume thresholds increase as people age. In addition, the disparity between low and high frequency sounds grows. To be audible to someone aged around 60 yrs, a high frequency sound needs be almost four~~4~~ times as loud as it would have been to be audible by someone aged 20 yrs.

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Figure 6. Volume thresholds for a hearing impaired individual (60 yrs) compared with an unimpaired age-match. Hearing impairment often affects only a portion of frequency space. The impaired individual shown here suffers severe impairment—very high thresholds—at 4 and 5 kHz, but appears otherwise normal compared with an age-matched control.

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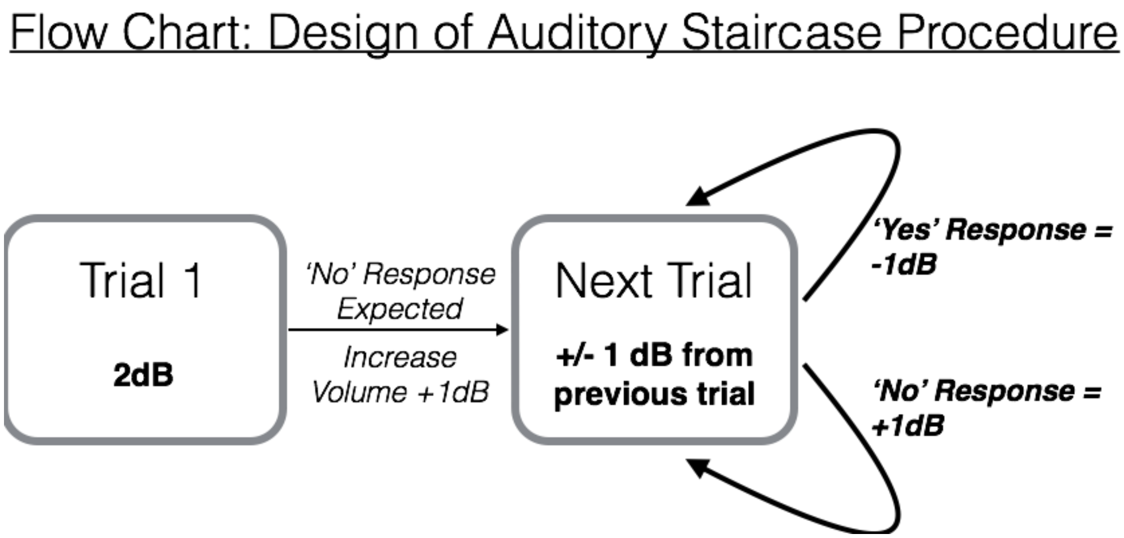
Figures



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A Table with Results from an Auditory Staircase Experiment

	A	B	C
1			
2	**Subject**	1	
3	**Frequency**	1000 Hz	
4			
5	**Trial**	**Volume**	**Response**
6	1	2	N
7	2	3	N
8	3	4	N
9	4	5	N
10	5	6	N
11	6	7	Y
12	7	6	Y
13	8	5	N
14	9	6	N
15	10	7	Y
16	11	6	N
17	12	7	Y

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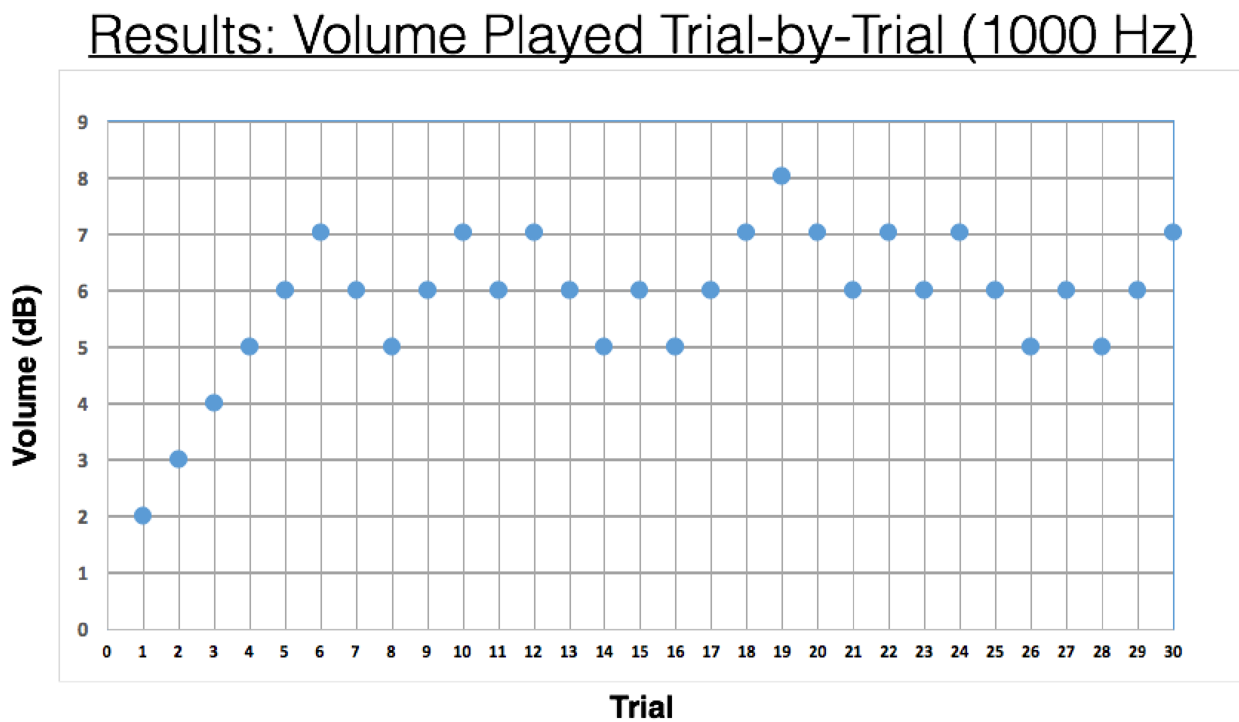

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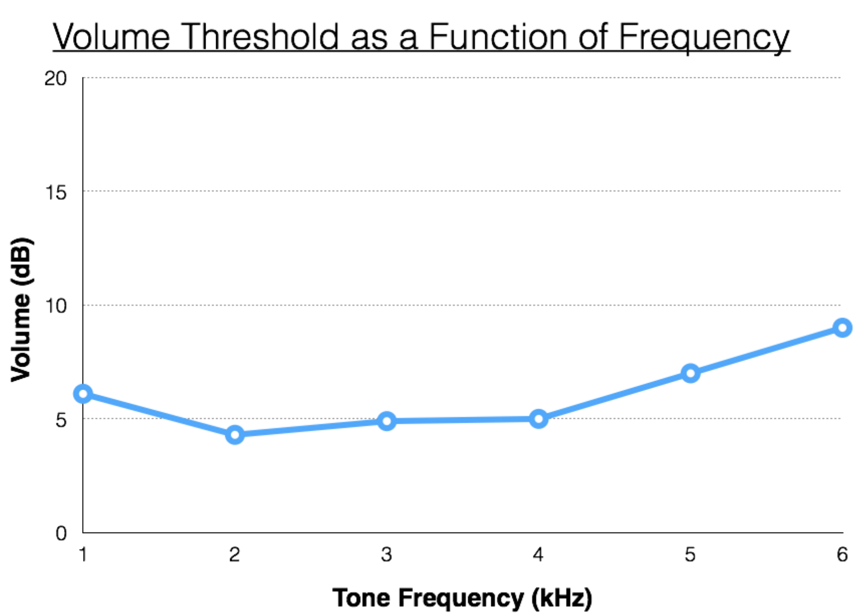

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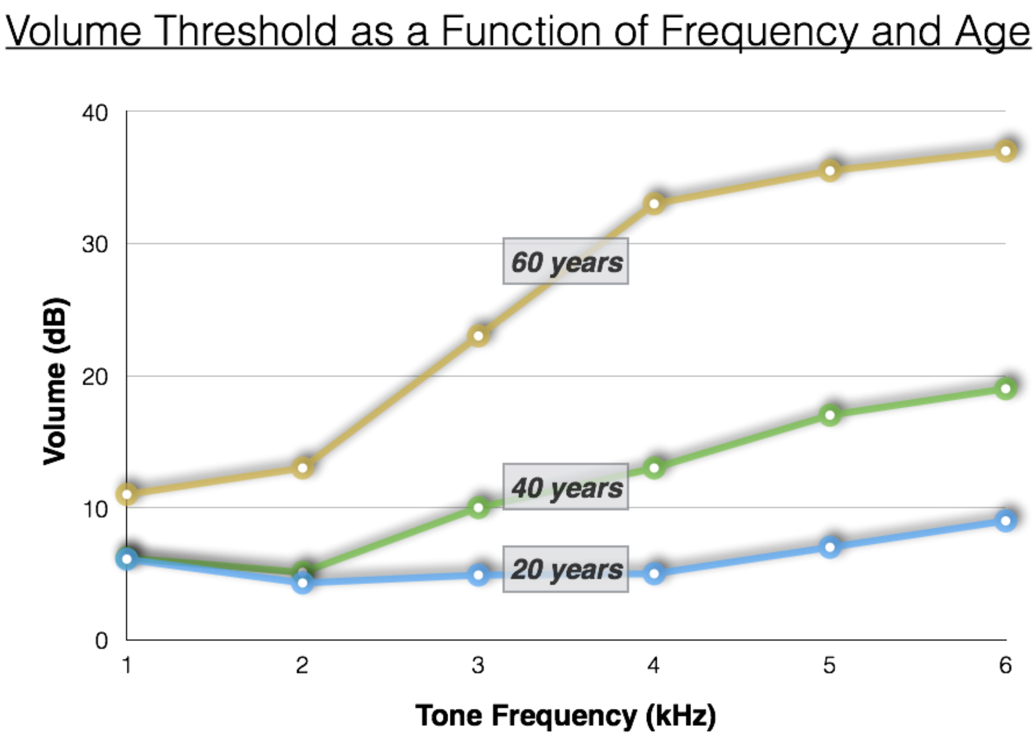

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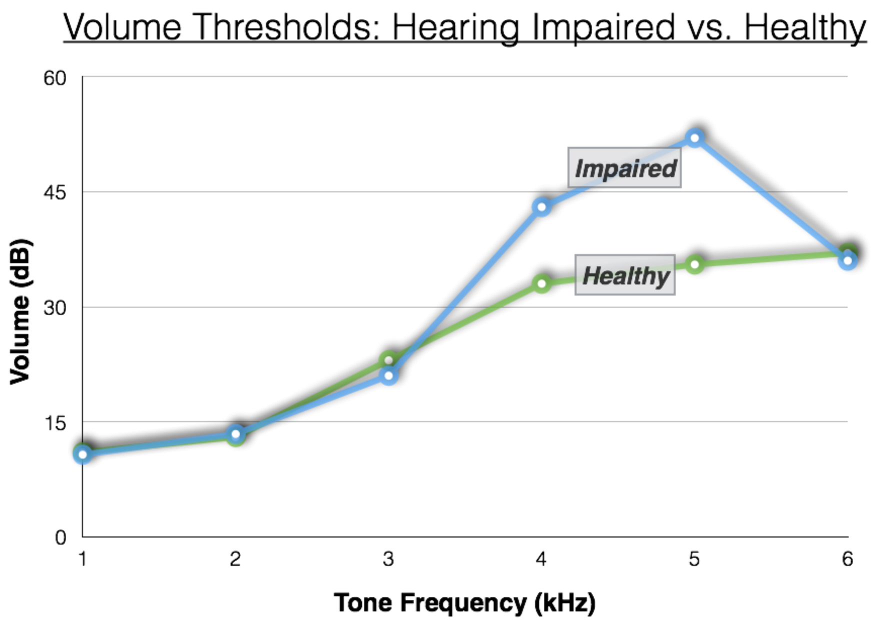

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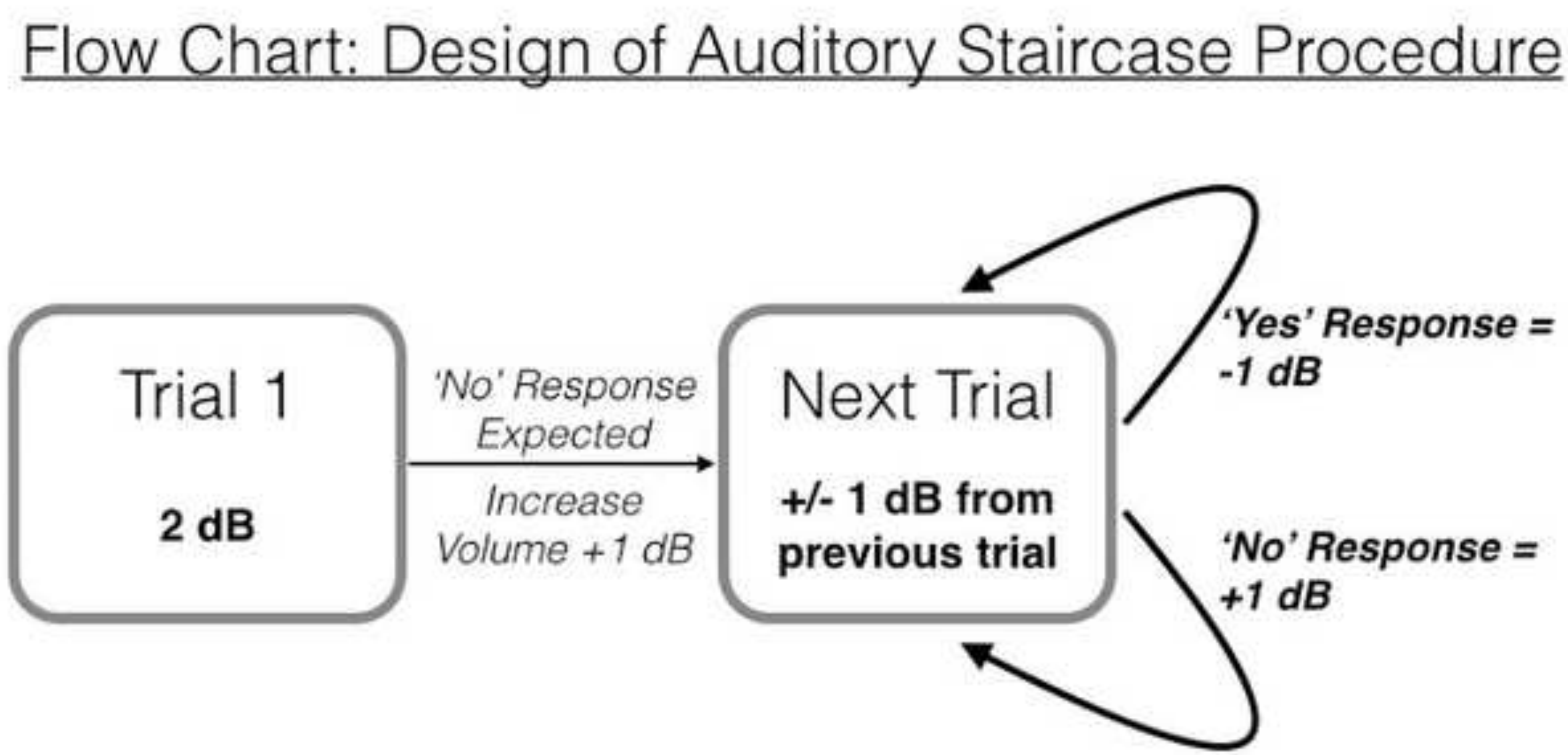
Flow Chart: Design of Auditory Staircase Procedure
Trial 1
2 dB
'No' Response Expected
Increase Volume +1 dB
Next Trial
+/- 1 dB from previous trial
'Yes' Response = -1 dB
'No' Response = +1 dB