An relationship between stress-less and comfortable acoustic information, and asymmetry changes in hemoglobin concentrations

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Abstract

We evaluated the effect of stress-less and comfortable acoustic information on the prefrontal cortex (PFC) activity. We measured the blood flow and hemoglobin concentration changes by Near Infrared Spectroscopy (NIRS) during listening to acoustic information. We observed that right and center PFC activity increases against unpleasant acoustic information. Left and center PFC decreases for user’s favorite and stress-less acoustic information. These results suggest that comfortable and stress-less acoustic information are discriminated by this observation method of asymmetric activities in PFC. The method can be applied to find stress-less acoustic resources and their stress-less and comfortable combinations.

Keywords: comfortable acoustic information; stress-less; blood flow; asymmetry change of activity in prefrontal cortex; NIRS

1. Introduction

Acoustic information makes people comfortable and pleasant in stressful society by good rhythms and melodies. The acoustic information also guides safe crossing by “Audible Pedestrian Signals (APS)” and easy transportation in stations and airports. A safe and comfortable mobility space makes pedestrians healthy and reduces the burden of medical expense in local government. However, acoustic information sometimes becomes stressful noise in a wide road and a station since a loud sound, curious tone, and so many repetition of a same sound put residents and workers great stress. Many APS have been stopped in both wide roads and quiet roads in residential areas in Japan.
People in aging society need stress-less and comfortable acoustic information. The efficiency of mental work under music conditions were investigated by using near infrared spectroscopy (NIRS). The relationship between skin condition and asymmetry in prefrontal cortex (PFC) activity during mental stress tasks was investigated by using NIRS. Modulating effects of food (Soy Protein Hydrolysate, etc.) for hearing music in PFC was discussed by using NIRS. We evaluated the effect of stress-less and comfortable acoustic information on the PFC activity. We measured relative changes in blood flow increases, the concentration of oxygenated hemoglobin (oxy-Hb) and deoxygenated hemoglobin (deoxy-Hb) during listening to acoustic information. We found a relationship between right/center/left PFC activity increase and acoustic information. The observation method can be applied to find stress-less acoustic resources and their stress-less and comfortable combinations.

2. Comfortable and stress-less acoustic information

Acoustic information and acoustic signs are very useful for home appliances, mobile terminals, car navigation systems, airports, train/metro stations, and Audible Pedestrian Signal (APS) at crossroad. Entrances in the stations, a toilet for male/female/handicapped person, and stairs are also guided for visually impaired persons and older persons by acoustic signs and voice guides in Japan. Human can easily trace continuous sound in loud noises but cannot discover an acoustic sign after a short pause in loud noises. Silences in a birdsong that is used as acoustic sign for APS, often cause failures in such discovery of the acoustic sign. Therefore, acoustic sign without silences is very important for visually impaired persons in loud background noise. We should introduce comfortable sounds and acoustic information in public spaces in order to make people safely take actions and enjoy pleasant time.

A loud sound, curious tone, and so many repetition of a same sound put residents and workers great stress. Our approach consists of three phases. (1) Discovery of the kinds of favorite sound sources, (2) evaluation of favorite sound sources by α-wave in brain, and (3) choice and evaluation of composed acoustic signs of favorite sound sources by NIRS.

(1) Discovery of the kinds of favorite sound sources. Human brain produces α-waves when a person hears comfortable sound and becomes relaxed. There are many cool and comfortable sounds in public spaces, such as stations, airports and museums, etc. However such cool sounds in Metro in Nagoya city did not let a person produce α-waves in our experiments although he felt the sound cool. We should improve noisy acoustic signs.

We discovered and selected 30 kinds of favorite sound sources as well as 17 kinds of unpleasant sound sources by questionnaires. The former includes sound of waves in beachside, flows in river, water drops, music boxes, the rustle of leaves, bird singing, church bell, wind chime, drop dripping, and harmonica, etc. The latter includes sound of scratching a blackboard, train brake, metallic sound, bike, siren, mosquito flies, and roar of airplane, etc.

(2) Evaluation of human’s favorite sound sources by α-wave in brain. Sounds of church bells and water drop in a small space (named “SUIKINKUTSU”), and melody of advertisement/animation let a person produce α-waves in his brain in our two experiments. People often miss some sound source in loud background noises since it include silences in it. For example, birdsong of APS includes such silences.

(3) Choice and evaluation of composed multiple favorite sound sources by NIRS. Continuous acoustic signs are effective for the people to trace them in loud background noises. We recorded sounds in the nature and gather good sounds in “Youtube”.

(i) Choose comfortable sound sources that let a human brain produces α-wave
(ii) Choose comfortable composed acoustic information that was composed of multiple comfortable sound sources.
(iii) Choose comfortable acoustic information that was composed of multiple comfortable sound sources. Check the α-wave of a listener when he listened to composed acoustic information although each sound source let a person produce the α-wave.

3. Experiment

3.1. Test 1. Evaluation of favorite sound source by α-wave in brain

(a) Favorite acoustic information let a person produce α-wave in brain.

We detect alpha-wave ("α-wave") in brain for nine kinds of favourite acoustic information. (i) the boom of cathedral
bell of Vatican, (ii) Echo by drops of water in a cave (named “SUIKINKUTSU”), (iii) Wind-bell (WB), (iv) the boom of Japanese temple bell, (v) arrival/departure awareness sound in train station “Ebisu,” (vi) music box, (vii) harmonica, (viii) sand beach wave, and (ix) streams in a river.

(ii) showed the strongest $\alpha$-wave in brain. We heard that (v) has reduced the number of person that was rushing into a train at a departure time since a melody of acoustic sign gave passengers an image of relaxed scene that people enjoyed delicious beer. Passengers not only feel comfortable but also remind composure and stop dashing so as to get on the next train. On the other hand, to our surprise, electronic music for arrival/departure awareness in Nagoya City Metro could not let a person produce $\alpha$-wave in brain although most people felt them cool.

3.2. Test 2. Composed acoustic information let human produce a long life $\alpha$-wave

Subjects. Four twenty’s (three men and one woman)
Target acoustic information: Subject’s favorite sound and composed acoustic information. (S1) “water flow in a river + music box,” (S2) “sand beach wave + music box,” (S3) “harmonica + music box,” and (S4) “sand beach wave + harmonica.”, harmonica, sand beach wave, sound in water flow, music box, the boom of cathedral bell of Saint Maria del Fiore, Echo by drops of water in a cave (“SUIKINKUTSU”), and Wind-bell.
Time periods. Test 2 consists of five time periods (from T1 to T5). T1: Before 1 minute, T2: During hearing (1 minute), T3: After 1 minute, T4: time for a rest (2 minutes), and T5: After 3 minutes. We mainly evaluated T3 and T5. The long time effects appeared at T5 (After 3 minutes).
Results.
(During hearing) All targets let human produce $\alpha$-wave. We found that S1 was better than S2. Composed sound of beachside wave and harmonica did not let a person produce $\alpha$-wave.
(After 1 minute) Acoustic information for $\alpha$-wave. All targets except for S4 let subjects produce $\alpha$-wave in their brains. Sand beach wave and harmonica were effective but S4 was not effective.
(After 3 minute) Acoustic information for $\alpha$-wave. The sounds of harmonica, sand beach wave, and S1 let subjects produce $\alpha$-wave in their brains.

3.3. Test 3. Choice and evaluation of composed multiple favorite sound sources by NIRS

Cerebral cortex old (almond, the nucleus acumens, and hippocampus) connects to cerebral neocortex, hypothalamus and brainstem. It affects the choice and decision making of actions. Activities in both frontal lobe and temporal lobe show major areas in the brain associated with comfortable acoustic information.
Subjects. Seven right-handed twenties (five males and one female).
Acoustic information. We choose target acoustic information in the targets in Test1 and Test2. (ai1) The boom of cathedral bell of Saint Maria Del Fiore, (ai2) Echo by drops of water in a cave (“SUIKINKUTSU”), (ai3) Wind-bell, and (ai4) “water flow in a river + music box.”
Table 1 shows favorite acoustic information of each subject.

| Subjects          | a, b, c, d | E   | f   | g   | h   | i   | j   |
|-------------------|------------|-----|-----|-----|-----|-----|-----|
| Favorite acoustic information | ai4         | ai3 | ai4 | ai3 | ai2 | ai3 | ai2 |
| Unpleasant acoustic information | ai2         | ai4 | ai1 | ai1 | ai4 | ai2 | ai3 |

Method. Measure and record relative changes in blood flow increases, the concentration of oxygenated haemoglobin (oxy-Hb) and deoxygenated haemoglobin (decoy-Hb) from the 16 channel points in PFC for each subject during next five procedures.
(i) Listen to an environment sound for one minute. The sound is a traffic noise at an intersection in Japan.
(ii) Listen to target acoustic information for one minute.
(iii) Listen to the environment sound for one minute.
(iv) Listen to the target acoustic information for one minute.
(v) Record additional changes in the haemoglobin (Hb) concentrations for several seconds
Measuring instrument. NIRS; Spectratech OEG-16 has 16 channel points in prefrontal cortex (PFC) (Fig. 1).

![Fig. 1. Images of Spectratech OEG-16 and 16 channel points in PFC (http://www.spectratech.co.jp/product/productOeg16.htm).](image)

Results.

(Test 3-1) Unpleasant acoustic information
“ai1 (cathedral bell)” was unpleasant acoustic information for both f and g as they answered in the questionnaire. The blood flow (in red) and the concentration of oxy-Hb (in green) of both f and g at point No. 7 in right front PFC relatively increased against the first unpleasant acoustic information (Fig. 2 (b) f1, g1). This increase shows stress against the unpleasant acoustic information. They decreased in the first half of second listening. The decrease means a sedation state that brain tried to stand the bitter experience of unpleasant acoustic information. We estimate that “f” and “g” could suppress unrest of hearing unpleasant acoustic information. However “f” and “g” could not suppress the unrest after about 30 seconds by unpleasant acoustic information (Fig. 2, (b), (c) f2, g2). The blood flow and the concentration of oxy-Hb at No. 9 in front low PFC increased as nearly same as those at No. 7. Those of g1 in the first listening steeply increased after 45 seconds. We found that No.7 and No. 9 showed stress against long unpleasant acoustic information.

![Fig. 2. Activities at No.7 and No. 9 points in PFC. “X”1 and “Y”2 mean results in T3 and T5, respectively.](image)

(Test 3-2) Comfortable and stress-less acoustic information
The blood flow and the concentration of oxy-Hb of both “a” and “c” for ai4 at both points of No. 9 (low center PFC) and No. 10 (front left PFC) relatively decreased for comfortable acoustic the comfortable acoustic information (Fig. 3). The decrease means a sedation state. We found that the decreases in T5, like a2, at point No.10 and No. 9 shows long effects for four minutes although effects of most acoustic information did not continue in strong for such a long
time. On the other hand, the blood flow and the concentration of Hb of c increased in c2 (second listening). We suppose that c had a spare to think of more pleasant space and events, etc. when he listened to the comfortable acoustic information twice. β-endorphin, etc. would be secreted in order to become more comfortable. On the other hand, relative concentration of both oxy-Hb and the blood flow of both b and f at points No. 9, No. 10, and No. 7 decreased for comfortable acoustic information (Fig. 4). These results indicate that the changes of blood flow and the concentration of oxy-Hb at points No. 9 and No. 10 in PFC show the effects of the comfortable acoustic information.

![Fig. 3. Blood flow increase, and changes of the relative concentration of oxy-Hb and deoxy-Hb of “a” and “c”](image_url)

![Fig. 4. Blood flow increase, and changes of the relative concentration of oxy-Hb and deoxy-Hb of “b” and “f”](image_url)

Discussion.

We should prepare comfortable and stress-less acoustic information for most people since acoustic information is heard by all people in the same space. Our results suggest that we should find and remove unpleasant acoustic information by observing the increase of blood flow and the relative concentration of oxy-Hb in the right and centre PFC.

Moreover, we should choose stress-less acoustic information from lots of pleasant acoustic information. We found that the effects of composed acoustic information of multiple favourite sound sources were long life more than four minutes. Such composed acoustic information should be chosen by observing how decrease of the blood flow and the relative concentration of oxy-Hb in both left and centre PFC of most people changes.

Acoustic information of audible pedestrian signal (APS) needs frequent repetition of acoustic information that does not include silences. We found that some subjects changes the activities in PFC after about thirty seconds. We should choose stress-less acoustic information and switch it after 30 seconds corresponding to either the people in the same space or some time periods in a day in order to avoid frequent repetition of the same acoustic information.

We also found strange activities that the blood flow and the relative concentration of oxy-Hb in both right and centre PFC decreased although echo by drops of water in a cave (“SUIKINKUTSU”) was unpleasant for subjects. The effects of dissonance by echo and a kind of flutter echo are future issues.
4. Conclusion

We measured the blood flow and the relative concentration of oxy-Hb by NIRS during listening to acoustic information. We observed that those at right and centre PFC increase against unpleasant acoustic information. Those at left and centre PFC decrease for user’s favourite and stress-less acoustic information. These results suggest that we should choose comfortable and stress-less acoustic information by observing the blood flow and the relative concentration of oxy-Hb at those points in PFC. The method is also applied to find stress-less acoustic resources and their stress-less and comfortable combinations.

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