Is a good soundscape element a restorative environment factor in open office?

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ABSTRACT
Some research has proved that a good environment preferred by people has a restorative function and can relieve people’s tiredness and stress. Then the question is whether a good soundscape element has also a restorative effect on people and can help them get rid of tiredness particularly when they feel some working stress in open office. In this study the restorative function of soundscape elements was proved by laboratory experiments and how to add the soundscape elements into the open office in order to give consideration to both effect and efficiency was also explored. As a result it showed that the good soundscape elements had an apparent effect on tiredness restoration and annoyance improvement. Compared with visual scene, sound had more effect on tiredness restoration in the condition of open office.

Keywords: Soundscape Element, Restorative Factor, Open Office
I-INE Classification of Subjects Number(s): 56.3, 63.5

1. INTRODUCTION
Restorative environment was put forward as a concept in the beginning of 1990’s and it means natural environment can play a central role in reducing mental fatigue (1). From then on many studies have carried out to reveal what kind of environment has restorative function and what are the characteristics of those environments. Kaplans have concluded that a restorative environment should have four characteristics, which are being away, extent, fascination and compatibility (1, 2). Very similar inference are obtained by most of the studies and it seems that field environment and favorite environment by people have more restorative function than other kinds of environment (3, 4). Several researches also made further efforts on what kind of people’s mental and physical condition would be restored by their favorite environment and it showed that besides mental fatigue, voluntary and involuntary attention capacity could be affected actively by the restorative environment (5).

Until now most of the studies on restorative environment mainly focused on the function of visual scenes. Then the question is whether or not a good sound environment can also have restorative function on people after all they perceive the external world not only through eyes but also through ears and other sensory modality. Research has proved that people would restore from fatigue to differing degrees as a function of environmental conditions, and the restorativeness order was a nature movie with nature sounds, nature sounds, silence and noise (6). That is to say special sound environment has restorative function whatever it is exposed to people singly or with visual scene.

The consensus has been reached that soundscape design is a good method to improve environment quality with the advancement of soundscape research. An optimized environment after adding soundscape elements should be more comfortable than the before, therefore it might also have more restorative function on people’s mental fatigue and give more help on people’s cognitive process. Is that true? Is a good soundscape element a restorative factor? How could we add the soundscape elements into environment in order to increase its restorative function?

In this study three experiments were carried out in order to explain the following questions: 1) Whether or not the good soundscape elements preferred by people have effective restorative function

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on mental fatigue and cognitive capacity? 2) How the soundscape elements can be added into 
original environment to fulfill and keep their restorative effects? 3) What is the interaction of visual 
scene and sound factor in restorative environment? Considering lower satisfaction, lower work 
productivity and poorer health was more frequently reported among the employees in open-plan 
offices compared to traditional offices (7, 8), all the experiment conditions were set according to 
open-plan office which was also a very popular office style in China.

2. RESEARCH METHOD

2.1 Subjects
15 different subjects participated in each experiment respectively. All the 45 subjects were 
graduate students of Tianjin University with different research background such as architecture, 
urban planning, chemical engineering, material science and so on. The average age of the subjects 
were 25 years old, and their working status and stress level were very similar with the young 
employees who worked in the open-plan office. In each experiment the ratio of the male and female 
subjects was almost kept as 1:1.

2.2 Experiment Stimuli
Experiment 1: According to the preliminary investigation about subjective preference on different 
sounds, five sounds such as flowing water sound, birdsong, footsteps, traffic noise and 
air-conditioner noise, were selected as the sound stimuli used in the experiment. There were two 
reasons to use those sounds as the stimuli in this experiment: 1) People’s attitude to those sounds 
was from active to negative. Flowing water sound and birdsong were evaluated to be the best 
favorite sounds by people, meanwhile footsteps, traffic noise and air-conditioner noise were 
classified as disliked sounds. 2) Those sounds are popular sounds in open-plan office or very easily 
to be added in the environment of open office. All the sound stimuli used in the experiment were 
recorded by researchers except that birdsong was downloaded from British Library Sound Archive. 
The length of each sound was set as 3 min with a sound pressure level of 55 dBA, which was 
reported by subjects to be the most comfortable sound level in a semi-anechoic room used to 
simulate the open office.

Experiment 2: Considering the convenience and possibility of adding sound element into the 
environment of open office, flowing water sound was used as the sound stimuli in experiment 2. The 
consistent water sound and 10 sec and 5sec water sound with sound pressure level of 55dBA were 
used. The interval of the intermittent water sounds was set purposely.

Experiment 3: In the third experiment both air-conditioner noise and flowing water sound were 
used as passive and positive acoustic factor respectively to match different visual scenes. Two 
photos selected by subjects through preliminary survey as the best and the worst visual scenes from 
120 photos taken in different open offices were adopted as the visual stimuli. Altogether 4 
audio-visual stimuli were made with the time duration of 3 min.

2.3 Experiment Tasks and Measurement Indicators
5-min calculation task was used to create stress and mental fatigue. The detailed calculation task 
was asking subjects to do continuous subtraction from 1895 with the step of 13. If the subjects did a 
miscalculation, they would be requested to stop and started their calculation from 1895 minus 13. 
This method was proved to be an effective way to raise people’s stress and mental fatigue by former 
study (9).

As for the indicators measured to represent subjects’ stress and fatigue level, three aspects were 
considered: 1) Physiological indices including systolic pressure, diastolic pressure and pulse rate; 2) 
Self-evaluation scales on the extent of tension, fatigue and annoyance, which were extracted from 
POMS (Profile of Mood States); and 3) Task Performance, that was to find a target figure from many 
similar figures correctly as soon as possible (Figure 1). All together 7 indicators from those three 
aspects were used to indicate subjects’ stress and fatigue status.

Figure 1 – Samples of the figures used in target-searching task
2.4 Experiment Steps

Figure 2 shows the process of experiment 1. Before the formal experiment, the subjects were asked to do some preliminary activities to understand the experiment process. The formal experiment consisted of 5 units and each experiment unit included 4 steps: 1) 5-min calculation: the subjects were guided by the researcher to do subtraction from 1895 with a step of 13. 2) Indicator measurement: after 5-min calculation subjects’ physiological and psychological status was measured using instruments and self-reported scales. Meanwhile the subjects were asked to do 1-min target-searching task. All the indicators measured in this step were used to show subjects’ original status after 5-min calculation task. 3) 3-min sound stimuli broadcasting for experimental groups and 3-min silence for control group. Five sound stimuli were chosen randomly for five experiment units. 4) Indicator measurement: the measured indicators were completely same as the step 2. The purpose of this measurement was to reveal subjects’ status after 3-min sound broadcasting or silence. All together five experiment units needed to be carried out. There was 2-min rest between each two experiment units.

![Diagram of experiment steps](image)

Experiment 2 and 3 followed almost the same process as experiment 1. The main difference of those three experiments was sound stimuli. In experiment 1, the sound stimuli consisted of five different sounds that were flowing water sound, birdsong, footsteps, traffic noise and air-conditioner noise. In the experiment 2, sound stimuli were five kinds of water sounds with different broadcasting methods (Figure 3). In the experiment 3, the stimuli were replaced by audio-visual stimuli, which were the combination of positive or passive sounds with positive or passive visual scene.

All the experiment settings were tried to set as similar as the situation of open office.

![Configuration of sound materials](image)
3. RESULTS AND DISCUSSIONS

3.1 The Restorative Function of Different Sound Elements

In all the experiments researchers valued the difference of each physiological factor, psychological indicator and task performance between before and after sound stimuli (audial-visual stimuli in experiment 3) broadcasting. Except task performance, the lower value means better restorative function brought by sound stimuli or audial-visual stimuli.

Table 1 showed the effect of different sound elements on restorative function by ANOVA analysis. Among the 7 indicators, the restorative function from fatigue and annoyance reported by subjects were significant influenced by different sound elements at 0.05 level. This phenomenon was same for both female and male subjects. That is to say, comparing with physiological indicators and working performance, psychological indicators such as self-evaluated annoyance and fatigue status were more sensitive to acoustic environment. Whether the physiological indicators and task performance are stable and can not be changed easily within several minutes or sound environment had no restorative function on physiological indicator and task performance needs further research.

Table 1-Effect of different sound elements on restorative function

<table>
<thead>
<tr>
<th>Sound Type</th>
<th>WE</th>
<th>T</th>
<th>F</th>
<th>A</th>
<th>SP</th>
<th>DP</th>
<th>PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>0.715</td>
<td>0.538</td>
<td>0.041*</td>
<td>0.025*</td>
<td>0.435</td>
<td>0.603</td>
<td>0.409</td>
</tr>
<tr>
<td>Gender</td>
<td>0.427</td>
<td>0.579</td>
<td>0.785</td>
<td>0.526</td>
<td>0.142</td>
<td>0.117</td>
<td>0.721</td>
</tr>
</tbody>
</table>
* means significant influences at 0.05 level. WE, T, F, A, SP, DP, and PR represent working efficiency, tension, fatigue, annoyance, systolic pressure, diastolic pressure and pulse rate respectively.

Figure 4 showed the effects of different sound elements on subjects’ physiological indicators, psychological indicators and working performance. From the figure it could be seen that subjects’ annoyance and fatigue restored more significantly after the subjects were exposed to the flowing sound and birdsong rather than the other three sounds, which were footsteps, traffic noise and air-conditioner noise. This tendency was same for the indicator of tension though the difference was not significant. However there was not consistent tendency on physiological indicators and task performance, and it showed that those indicators varied with different sound elements added into the environment casually. Because water sound and birdsong were liked by people and considered as good soundscape elements, it could be concluded that adding good soundscape elements into environment could increase restorative function of the environment at least for the restoration of annoyance and fatigue.

Figure 4- Effect of different sound elements on physiological indicators, psychological indicators and working performance (AN and TN represent air-conditioner noise and traffic noise respectively)
3.2 The Effect of Adding Method of Soundscape Element on Restorative Function

Table 2 was the ANOVA analysis on restorative function of different adding methods of flowing water sound into simulated open office. Except pulse rate, there was no significant effect of different adding methods of water sound on its restorative function. Therefore whether the added sound was constant or not did not influence its restorative function and adding the good soundscape element discontinuously might be an efficient method for environment improvement.

Male and female subjects showed different recovery extent from tension, fatigue and annoyance under different adding methods of flowing water sound. Comparing with female subjects, male subjects got more recovery from the original tense, annoyed and fatigue status if adding flowing water sound into the simulated open office situation whatever the adding method was (Figure 5). Also male subjects were more sensitive to the varying of adding method of flowing water sound. That is to say deliberate soundscape design was necessary for the open office where majority of employees were male.

Table 2: Effect of adding methods of flowing water sound on restorative functions

<table>
<thead>
<tr>
<th>Sound type</th>
<th>WE</th>
<th>T</th>
<th>F</th>
<th>A</th>
<th>SP</th>
<th>DP</th>
<th>PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>gender</td>
<td>0.801</td>
<td>0.665</td>
<td>0.943</td>
<td>0.571</td>
<td>0.387</td>
<td>0.214</td>
<td>0.044*</td>
</tr>
</tbody>
</table>

* and ** means significant influences at 0.05 and 0.01 level. WE, T, F, A, SP, DP, and PR represent working efficiency, tension, fatigue, annoyance, systolic pressure, diastolic pressure and pulse rate respectively.

Figure 5- Effect of different adding methods of flowing water sound on psychological indicators (Type 1: continuous water sound; Type 2: intermittent water sound, 10s water sound and 10s silence; Type 3: intermittent water sound, 10s water sound and 5s silence; Type 4:intermittent water sound, 5s water sound and 10s silence; Type 5:intermittent water sound, random duration for water sound and silence)

3.3 Comparison of Restorative Function of Visual and Audial Factors

Sometimes it is difficult to change both visual scene and acoustic condition in certain environment to increase its restorative function on people’s fatigue particularly for open office. Therefore the interaction of visual and audial factors on environmental restorative function was worthy of being discussed in order to redesign the present environment effectively. Table 3 showed the effect of four audio-visual stimuli (positive visual scene plus positive sound element; positive visual scene plus negative sound element; negative visual scene plus positive sound element; negative visual scene plus negative sound element) on environmental restorative function. As the same of former experiments subjective fatigue and annoyance level were very sensitive to the audial-visual stimuli and their restoration extent varied with different audial-visual conditions. For most of indicators there was no gender difference.

Table 3: Effect of different visual-audial stimuli on restorative function

<table>
<thead>
<tr>
<th>Material type</th>
<th>WE</th>
<th>T</th>
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<th>A</th>
<th>SP</th>
<th>DP</th>
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<tr>
<td>gender</td>
<td>0.97</td>
<td>0.461</td>
<td>0.047*</td>
<td>0.018*</td>
<td>0.561</td>
<td>0.232</td>
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</tbody>
</table>

* and ** means significant influences at 0.05 and 0.01 level. WE, T, F, A, SP, DP, and PR represent working efficiency, tension, fatigue, annoyance, systolic pressure, diastolic pressure and pulse rate respectively.
Figure 6 was comparison of different audial-visual factors on their restoration function. The very interesting thing was that the restoration function of water was significantly better than air-conditioner noise whatever the visual scene was good or bad. This phenomenon was very apparent for the restoration of psychological indicators. Say it in other word, sound condition might have more function on the restoration of people’s fatigue. In the open office adding a suitable soundscape element was a better choice than changing visual scene for employees’ recovery of fatigue and stress. In this point further systematic research was needed.

![Graph showing interaction of visual and audial actors on physiological indicators, psychological indicators and working performance.](image)

**4. CONCLUSIONS**

In the simulated situation of open office, three experiments were carried out to explore the restoration function of soundscape elements. A good soundscape element liked by people had a good restorative function on people’s fatigue and stress though the restoration function was mainly on psychological aspect rather than physiological indicators and working performance. As for the same soundscape element, consistent sound did not show a better restorative function than intermittent sound, therefore adding method of the sound into open office could be decided by other consideration such as efficiency. Comparing with visual scene, sound had more effect on the people’s recovery from fatigue and annoyance though it still needed more systematic research.

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**REFERENCES**
