Original Article

Basic study on the effects of the use of BGM in auditory user interface on user's memory and learning of directory hierarchy

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Abstract

Purpose: To provide cues to users for grasping the directory hierarchy in the operating environments of information technology devices when it is extremely difficult to use the sense of sight, we devised a user interface having a type of auditory landmark by playing simple music with no particular semantic structure as background music (BGM) for specific hierarchies. We performed a basic study of the effect of BGM on the users' recall and learning of directory hierarchies and of the item names residing in them.

Subjects and method: The subjects were 12 healthy male university students between the ages of 21 and 22 (six for each of the experiment conditions). To avoid influencing the test results, we selected subjects who were not information science or music majors. We prepared a four-level tree-structured directory hierarchy, which was structured such that the first level had two branches, the second level had three branches, and the third level had three branches. There were 30 nodes and 80 items. We used information science terminology for the item names. The item names were read aloud using a screen reader. The arrow keys, enter key, and backspace key were used to move inside and between directories. We tested tasks of recall and learning of the directory hierarchy under two conditions: 1) with BGM (BGM was presented in three places in the hierarchy) and 2) without BGM. We performed six trials in total, two trials each day for three days.

Conclusion: Our findings are summarised as follows: (1) Memorising and learning by mapping the spatial arrangement of the directory with BGM enhanced the users' spatial perception of the directory structure. (2) As a result, learning performance increased approximately 20% on an average. (3) This increased relatively the cognitive processing resources for applying the item names into memory, and learning efficiency increased by an average of approximately 30%.

Keywords: Auditory user interface, Non-visual user interface, Visual impairment, Human memories, Learning, Directory hierarchy

Introduction

Electronic data such as files and menu commands are organised hierarchically using metaphors called tree structures in general information technology equipment including personal computers (PCs). The advent of the graphical user interface (GUI) made tree structures easier to recognise because the two-dimensional information improved users' visual perspicuity.

However, when people with severely impaired vision use PCs, they find it extremely difficult to obtain screen information visually. Besides, when sighted people drive vehicles, they must constantly monitor information coming from outside the vehicle; they may find it very difficult to obtain information visually from the monitors on information technology equipment.

Here, we propose a method of presenting screen information aurally by converting it to audio by means of application software that uses text-to-speech (TTS) technology called screen

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reader. For PCs, screen readers such as NVDA (NV Access, 2016) and PC Talker (Kochi System Development, 2016) are available. For on-board vehicle information devices, products such as Cybernavi (Pioneer, 2016) are available.

However, because the audio presented by such software is one-dimensional information, using it to enable two-dimensional perspicuity for the expression of directory structures is difficult. As a result, aurally expressing directory hierarchies in a way that is easy to understand is very difficult. Therefore, to solve this problem, methods have been proposed that use information from other sensory organs for information compensation. For example, in research with the visually-impaired as subjects, a method that displays directories haptically using a Braille display at the same time as the GUI display has been proposed (Yamanaka, 1997). However, in a mobile environment or in the vehicle-driving environment mentioned above, such devices will be difficult to install because of the limited space available and may interfere with the operation of the steering wheel.

Another method that can improve cognition is to use a different semantic information format for the same model. In particular, the sense of hearing has the characteristics of ‘background’ and ‘simultaneous hearing’ (Kramer, 1994), and hence devising a way of presenting multiple pieces of aural audio information simultaneously is possible.

Earcons are an example of a user interface (UI) that makes use of these characteristics. Earcons are a type of nonverbal audio message that provides users information about objects, operations and interactions on the computer (Blattner, 1989). If the tree structure directories in a file system are converted to audio, a user moving to a certain hierarchy is presented with auditory information containing spatial rules expressed as a specific timbre and a tonal scale, enabling the user to understand that particular location of the directory.

However, the authors believe that a directory structure can be memorised efficiently without increasing the cognitive load in information technology equipment operating environments where it is very difficult to use the sense of sight, by presenting the user at specific hierarchies with simple music that does not have a semantic structure, such as that of the earcons, in the form of BGM, making use of the above-mentioned ‘background’ and ‘simultaneous hearing’ characteristics of auditory information. The reason for this is that we think that BGM has the potential to become a type of spatial landmark. For example, when the user moves to a folder in the GUI environment, an assigned BGM is played while the user remains in the folder searching for a filename. It can be expected that if this is done, when the user associates the name of the location (folder name) with the BGM and remembers it, he/she will be able to differentiate that folder from the other folders, and spatial perception of the directory becomes easier. The reason for using BGM for differentiation is that by presenting the music sequentially, the users can be continuously notified of the fact that they stopped at that particular folder. As an example of the validity of a similar idea, one can point to the work of (Sakayori, 2003), which used five test subjects who were visually impaired. An auditory interface utilising auditory feedback was provided on an existing copier during GUI operation, and then evaluated. According to the research, the user interface was designed such that for moving the cursor on the copier operating screen and entering the number of copies, the same numeric keypad was used, and it was possible to input commands by switching between the two modes. It was reported that when the interface was used, when each of the modes was active, different BGMs were played sequentially, such that all subjects recognised the modes correctly, and there were no mistakes in the operation of the numeric keypad. However, there were only two modes in this investigation, and there was no quantitative evaluation.

Our research is a basic study of the effect of the presentation of BGM on cognition of a two-dimensional directory hierarchy, in particular on recall, learning and mental workload (MWL).

Experiment

1 Subjects

The subjects were 12 healthy male university students between ages 21 and 22 years (six subjects for each of the experiment conditions). To avoid influencing the experiment results, we selected subjects who were not information science or music majors.

2 Method of presenting stimuli

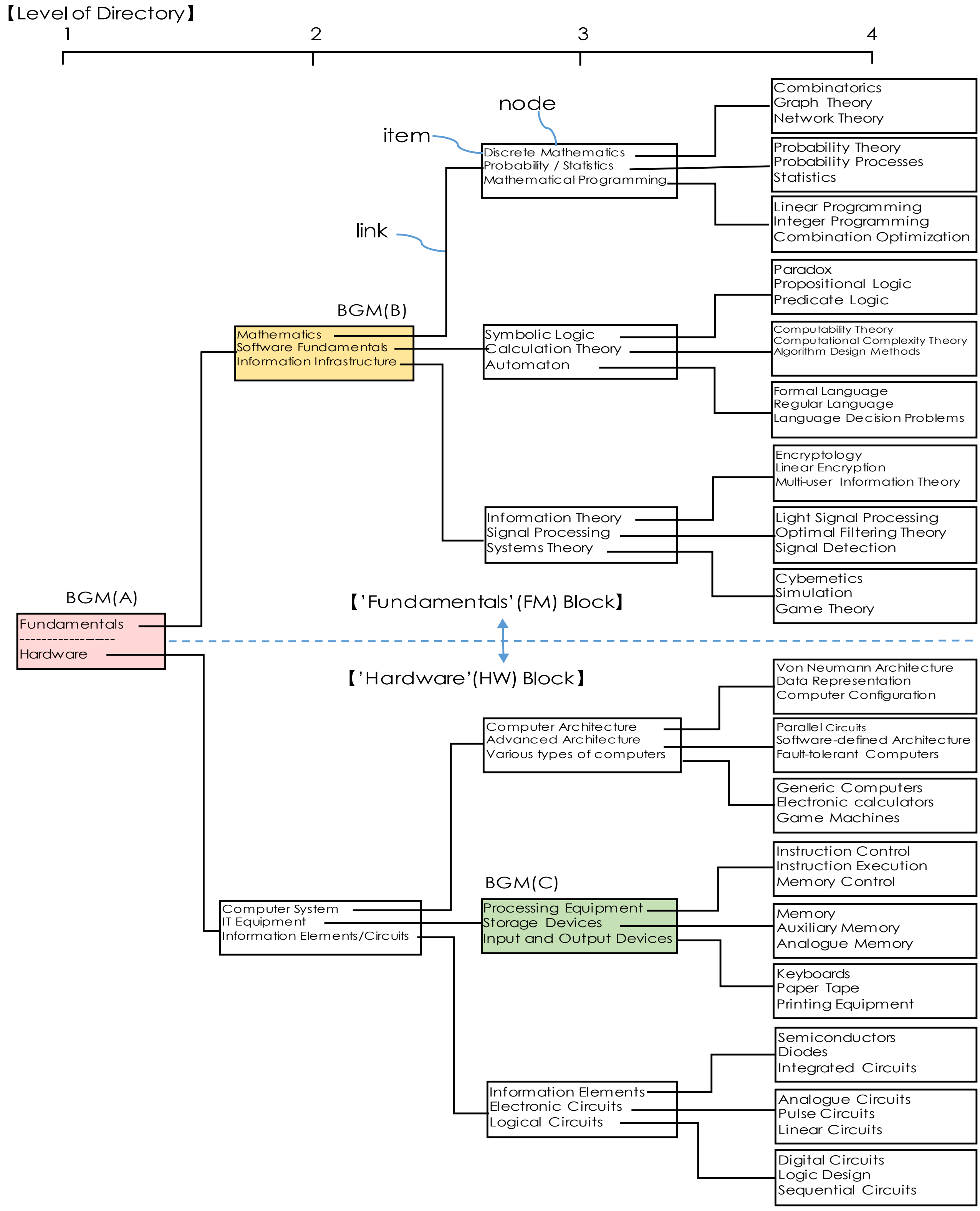

Figure 1: Terminology and directory hierarchy used in the experiment

The directory presented in the experiment has a two-block structure, with four levels, as shown in Figure 1. Nodes and links are defined as the elements making up the directory. The rectangular elements in Figure 1 are called 'nodes', and they are the same as 'folders' in a GUI. Elements (the present study used information science terminology) included in a node are called 'items'. The lines that connect nodes are called 'links'. A link connects an item in a node to another node one level below in the directory. The movement between nodes is described in Section 3.

Level 1 of the directory contains the root node. The root node contains two items, namely 'fundamentals' and the 'hardware'. When the user selects one of these items, he/she moves to the corresponding node in Level 2 in the corresponding block. These blocks are called the 'Fundamentals (FM) Block' and the 'Hardware (HW) Block', respectively. Three items are arranged in each of the nodes in Level 2 of the directory. Level 1 has 1 node, Level 2 has 2 nodes, Level 3 has 6 nodes, and Level 4 has 18 nodes; thus, the total number of nodes is 1 + 2 + 3 + 6 + 18 = 30. The root node in Level 1 has 2 links. Each of the nodes in Level 2 has 3 links and that in Level 3 has 3 links; thus, the total number of links is $2 + 2(3 + 3^2) = 26$. The root node in Level 1 has 2 items. In each block, each parent node in Level 2 has 3 items, parent nodes in Level 3 have 9 items, and child nodes in Level 4 have 3 x 9 items; thus, the total number of items is $2(1 + 3 + 3 \times 3 + 3 \times 3 \times 3) = 80$. By using terminology for item names that was as unfamiliar as possible to the test subjects, we controlled the level of difficulty of memorisation and structuring. Specifically, we used terminology for information science categories and tree structures from the 'terminology trees' in the Encyclopaedic Dictionary of Computer Science, Iwanami Shoten, Publishers (Nagao, 1990).

For the BGM group, we assigned three types of BGM to the three nodes, which are marked in pink, yellow, and green in Figure 1. We randomly assigned BGMs to each level. Using a preliminary investigation, we selected in advance each BGM that could be easily distinguished even by users without knowledge of music.

BGM-A: Classical music-like piano solo

BGM-B: Guitar chord strokes and base

BGM-C: Jazz-like swing drum and running base

The BGM sound pressure level (SPL) was 45 dB.

3 Experiment System

We created an experiment program to recreate moving between the nodes in Figure 1 without relying on the sense of sight at all. TTS (ProTalker 97, IBM) was used for the auditory presentation of the names of the items within nodes. Mouse operation was not used. Movement between nodes was performed using keyboard keystrokes only. The following is a more detailed description.

The up and down arrows on the keyboard were used move the selection (focus) on items inside the nodes. Another way to describe focus is that it is the user's current position. When the Enter key was pressed, the focus moved to a node in the directory one level below. When the Backspace key was pressed, the focus returned to one level up in the hierarchy. Each time the focus was moved using the above method, the item name in focus was read aloud in a TTS male voice. This operation is the same as the operation of the accessibility function used by Microsoft Windows OS.

The movement of the focus within the node was made to be noncycling. For example, if there are three items arranged in a node, even if the up arrow key is pressed while the focus is on Item 1, the focus does not move to Item 3. Similarly, even if the down arrow key is pressed when the focus is on Item 3, the focus does not move to Item 1. When the user did either of those things, a sound of something hitting a wall was presented, letting the user know that this was a dead end.

We gave the experiment program a function for recording a chronological log of which nodes and items the focus was moved to.

The experiment program operated over Windows XP on a PC (Dimension 8400, DELL), and the audio information reading out the item names was presented via headphones (MDR-Z600, Sony) at an

SPL of 60 dB. By presenting the read out auditory information 15 dB louder than the BGM, we created a master-servant relationship between the reading out of the item names and the BGM (the item names were the master).

4 Experiment tasks

We asked the subjects to operate the above-mentioned experiment system and to memorise as many as possible of the five types of information shown in Table 1 within the 20-min time limit per trial.

Table 1: Information to Memorise

No	Information to memorise
1	Item name
2	Location of the hierarchy that includes this item
3	Items within the hierarchy and their order
4	Content of BGM (BGM condition)
5	Location of the hierarchy where BGM is presented (BGM condition)

After the time limit for memorisation was over, we asked the users to recall what they had remembered. We distributed an answer sheet with the names of the items in each of the levels shown in Figure 1 left blank, with only the structure of the directory available, and asked them to fill in the item names based on their recall of the above-mentioned 1 to 3. However, we neither informed the subjects of their scores nor gave them the right answers at the end of the memory recall tests. The reason for not informing the scores was that we believed that this would affect the subjects' motivation. The reason for not giving the right answers was that this in itself would constitute learning.

Next, for the above-mentioned 4 and 5, we administered a recognition memory test. The method was to have the subjects listen through headphones to the three types of BGM and the BGM names in random order. Then we asked them to fill in the name of the BGM corresponding to the directory location that had been used to recall the item names on the answer sheet.

As existing environments, there were two testing conditions. The ‘no BGM condition’ only read out the item names. The ‘BGM condition’ added continuous playing of BGM in addition to reading out the item names when specific nodes were entered.

5 Evaluation Metrics

Learning Effect: Time series variation of percentage of correct answers

When all the memorised content (1 to 3 in Table 1) was correct, the number of correct answers was marked 1. However, for Number 1, even if the writing of the spelling was wrong, if the reading was judged to be correct, it was counted as a correct answer. These were totalled for each trial, and the total number of items was divided by 80; in other words, the percentage of correct answers was obtained using Equation (1).

Percentage of correct answers = Total number of correct answers in each trial/ Total number of items (1)

Learning effect was evaluated by expressing the time series variation of the percentage of correct answers for each trial.

Type of BGM and accuracy of recall of arrangement (BGM condition only): We investigated whether BGM was used correctly by performing a recognition test of the type of BGM and the position in the directory where the BGM was presented.

Learning Efficiency: When a certain item is correctly memorised, learning efficiency is considered to be higher when that item had been read out a fewer number of times. Therefore, learning efficiency was defined using Equation (2).

Learning efficiency = Number of correct answers/ Number of auditory presentations (2)

Mental workload (MWL):

We used the NASA-TLX as the indicator. It is a type of subjective evaluation method whereby the user responds concerning the six MWL scale items by placing marks on scales in the answer sheet corresponding to how high they evaluated each one. We used the adaptive weighted workload (Miyake, 1993), which is a simple data analysis method, to calculate total scores.

Self-Assessment Reports

After the experiment, we conducted interviews and received self-assessments of the cognitive processes during task performance.

6 Experiment Procedure

The experiment was conducted using the following procedure:

1) After receiving the instructions for the experiment, we had the subjects put on eye masks so that they could not use their sense of sight.

2) The subjects put on headphones. Then, for the first time only, we had the subjects operate the practice interface under each test condition for 10 min, so that they were sufficiently familiar with the UI operation and the experiment method. If the subjects felt that the practice was insufficient, we had them repeat it.

3) The first trial was carried out for 20 min. As soon as the first trial was finished, we had the subjects recall what they had memorised.

4) If BGM had been used, we ran a BGM recognition test.

5) We distributed the NASA-TLX questionnaires and obtained responses concerning MWL.

6) After that, there was a 20-min break and then we performed the second trial.

In this manner, we had two trials in a day. We did this for three days in a row, for a total of six trials. There was a 24-h gap between the days.

Results

1 Learning Effect

Figure 2 shows the relationship between the number of trials and the average percentage of correct answers. Overall, higher values were shown when BGM was used. The results of the initial trial and the sixth and final trial were 10.2% and 67.9%, respectively, for the no-BGM condition. By contrast, the results for the BGM condition were 11.9% and 87.1%, respectively. The BGM group's performance at the final trial was 19.2% higher than the no-BGM group.

Concerning the percentage of correct answers, we conducted paired t-tests to study if there was an observable difference for each experiment condition between the immediately previous trial and the current one. We used Microsoft Excel 2016 for the statistical analysis. The results showed significantly high results at a 1% standard from the previous trial to the current one, for all of the trials and for both conditions. The *p* values are shown in Figure 2.

Next, we conducted Mann–Whitney U tests to discover the difference in percentage of correct answers under BGM and no-BGM conditions for each trial. We used IBM SPSS 13.0J for statistical analysis of the Mann–Whitney U tests. The results showed that in the sixth trial, there was a significantly higher percentage of correct answers in the BGM group compared to the no-BGM group, at a 5% standard ($p = 0.016 < 0.05$). In other words, up to the fifth trial, both groups had equivalent performance, but at the sixth trial, the learning effect in the BGM group was remarkably higher.

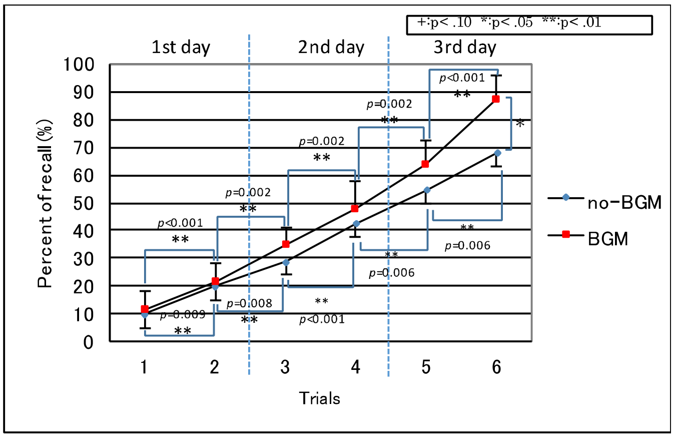

Figure 2: Trial and percent of recall (mean and SD, two trials of six subjects)

In the BGM recognition tests, the percentage of correct answers in Trials 1 through 6 were 66.7%, 72.2%, 83.3%, 94.4%, 100.0%, and 100.0%, respectively. The wrong answers were all in the HW block. The type of BGM was correctly identified but a different node was identified. Therefore, this shows that all of the subjects had 100% recall of the BGM in the Level 1 directory and the FM block from the very first trial.

2 Learning Efficiency

Regarding learning efficiency, for each experiment condition, we performed the Wilcoxon signed-rank test on the differences between the experiment days, and revised it based on the Bonferroni inequality. We used IBM SPSS 13.0J for the statistical analysis. The results showed statistically significant differences among all of the experiment days, for both experiment conditions, at 1% standard (p = 0.002 for all experiment conditions and experiment days). From this, we knew that learning efficiency improved as the days went by, regardless of whether BGM was presented. In particular, on the third day, the BGM group had an average efficiency that was 32.3% higher.

Next, we conducted Mann–Whitney U tests to discover the differences between experiment conditions for each day of the experiment. We used IBM SPSS 13.0J for the statistical analysis. Between the second and third days, under the no-BGM conditions, differences were marginally significant (p = 0.079) at 10% standard, and under the BGM conditions, differences were statistically significant (p = 0.023) at 5% standard (2nd day: p = 0.045 < 0.05, 3rd day: p = 0.068 < 0.1). From this, we learned that starting from the second day, the BGM group showed an improvement trend in learning efficiency.

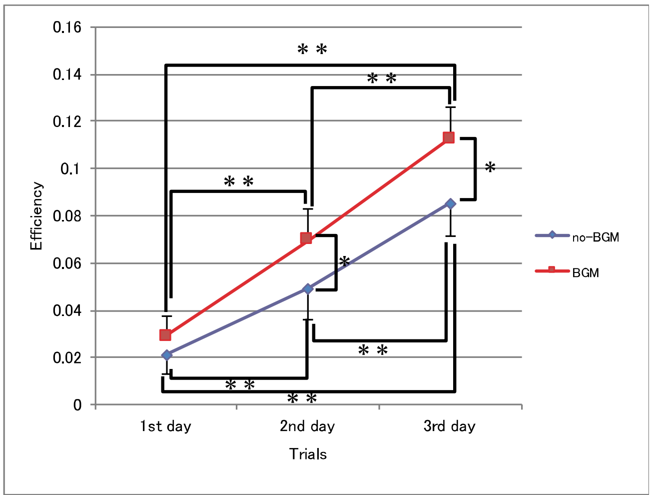

Figure 3: Changes in learning efficiency by day

3 Mental workload

Figure 6 shows the daily changes in MWL. From the fact that MWL decreased on the third day, we learned that MWL decreased after a learning strategy was established. Therefore, we performed paired t-tests to observe if there were differences in MWL between the immediately previous experiment day and the current experiment day, for each test condition. We used Microsoft Excel 2016 for the statistical analysis. The results for the difference between the second day and third day for no BGM showed a statistically significant difference (p = 0.079) at 10% standard, and the results for BGM showed a statistically significant difference (p = 0.023) at 5% standard. Next, we conducted Mann–Whitney U tests to discover the difference between experiment conditions for each experiment day. We used IBM SPSS 13.0J for the statistical analysis. As a result, no statistically significant difference was observed between the conditions.

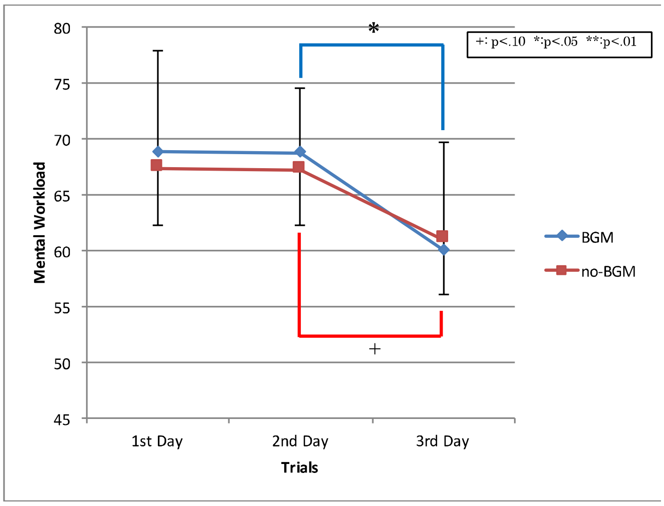

Figure 4: Changes in MWL by day

4 Self-assessment reports

Among the self-assessment reports obtained through interviews, the content of the responses from multiple subjects is shown below. The figures inside the parentheses show the ratio (%) of the numbers of respondents.

(1) The group without BGM:
a) At the beginning, there were lots of times when I did not know where I was, and I got lost. However, after the second day, I was able to grasp all of it. (67)
b) I did not understand very much of the meaning of the terminology and the relationships among the nodes. (67)

(2) The group with BGM:
a) From the beginning, I was able to figure out the position of the current node by using the node where BGM was playing as a starting point. (83)
b) The music made me feel relaxed and my brain felt refreshed. (50)
c) A lot of times I did not understand the meaning of the terminology or the relationships among the nodes. (67)

Discussion

Learning efficiency rose as a result of the establishment of a learning strategy making effective use of BGM on the second day. It can be said that a clear learning effect difference appeared as the subjects went into the third day. However, we did not observe great differences in movement patterns, in other words, learning patterns. Therefore, it can be said that this was not due to the differences in the subject's searching behaviour, and was due to the influence of the presence or absence of the BGM information. Furthermore, the directory hierarchy used in this study was configured from information science terminology divided into categories. Normally, memorisation is enhanced if category information can be utilised. However, from self-assessment reports (1)b and (2)c, many of the subjects did not understand the meaning of the terminology, and hence were unable to make effective use of the categories. As a result, as shown in self-assessment report (1)a, we believe that they were not able to memorise the relative positions of the nodes during the learning period. Meanwhile, in the BGM group, as demonstrated in self-assessment report (2)a, almost all of the subjects succeeded in learning the directory hierarchy. Next, we will add our observations on how using BGM increased learning efficiency.

From the standpoint of cognitive information processing, the main tasks in this experiment can be divided into three types of memory elements.

Memory Element 1) Perception and memory of the spatial information of the directory hierarchy
Memory Element 2) Memory of verbal information, the names of the items inside the nodes
Memory Element 3) Perception and memory of the BGM inside the nodes

It is thought that human beings have resources for information processing, and that each time a task is performed, the required amount of resources are allocated. It is thought that there is a set limit to the total amount of resources, and that each task is performed within the limits of these resources. At the same time, it means that the more the number of tasks performed, that much more resources are consumed. When the amount of resources required for these activities exceeds the total amount of resources possessed by each individual, a resource sufficient for each activity cannot be allocated. It is believed that this causes interference among tasks, and performance at tasks is reduced (Ohta, 1990). One of these kinds of processing resource theories is Wickens' multiple-resource theory model (Wickens, 1984). In this model, resources are composed of two-dimensional elements called modalities and processing codes. Modalities are composed of the visual and the auditory components. Processing codes are composed of the spatial and the verbal components. The types of resources to apply are determined by the combination of these two-dimensional elements. Then, the activity is carried out as a result of processing during stages composed of encoding, central processing, and responding.

Therefore, when multiple tasks that require the same types of resources are carried out at the same time, tasks that cannot secure sufficient resources due to competition for application of resources are impeded. Considered from this line of thought, the above-mentioned Memory Elements 1 and 2 are processed using different codes. Meanwhile, Memory Elements 2 and 3 are processed using the same modality, the auditory one. When we apply a broad interpretation of Wickens' model, it is conceivable that as music is nonverbal information, each memory element is processed using a different code. Therefore, it is conceivable that competition for resources did not occur in the above three types of memory tasks.

Besides, Memory Element 3 required the memorisation of the association of spatial information with auditory information. Therefore, it is conceivable that in the memorisation process, the BGM is elaborated on the position information. This is backed up by the results of self-assessment (2)a. Hence, it is conceivable that the amount of cognitive resources required to learn the nodes in Memory Element 1 decreased due to this elaboration and increased the relative amount of resources applied to memorising the items. It is conceivable that learning efficiency and learning effect improved as a result. Regarding this point, from the results of the BGM recognition memory test, the fact that all of the test subjects had 100% recall of the BGM in the Level 1 directory and the FM block from the very first test shows that all subjects started their learning process from the FM block. It can be surmised that first they memorised the location of the node where BGM was playing. Then, as shown in self-assessment report (2)a, they used the strategy of using the BGM node as a starting point for locating the current node.

Furthermore, the possibility exists that the activation of mental activity from listening to BGM made a contribution. Even though it does not deal with long-term memory the way this study does, research (Soma, 2005) has shown clearly using a flicker test that if relaxing music is presented during tasks when mental arithmetic, employing short-term memory, and thinking are performed simultaneously, not only is performance of the task improved but mental fatigue is suppressed. In this study as well, the possibility exists that BGM, by suppressing mental fatigue, caused the activation of the central executive for working memory, and this exerted a beneficial effect on memory and learning performance. This was not demonstrated quantitatively in the MWL results. However, we believe that there is a relationship between the use of BGM and improved memory and learning performance of the subjects from the self-assessments of half of the subjects who reported that the presentation of the music made 'my brain feel refreshed' and 'made me feel relaxed'.

The possibility exists that these reports demonstrate that BGM not only increased learning efficiency and the percentage of correct answers, but also exerted a beneficial effect on MWL as well. Even though the addition of BGM increased the amount of perceptual and cognitive information, MWL did not increase compared to the no-BGM case. When we consider this in conjunction with the fact that learning efficiency was higher with BGM, we learned that it is possible to obtain an even higher learning effect with equivalent MWL as before by the addition of BGM.

Furthermore, the day-to-day changes in MWL showed similar trends regardless of the existence of BGM, and on the third day, it decreased greatly. If the percentage of correct answers and learning efficiency results are compared, when the percentage of correct answers exceeded 50% and the learning efficiency exceed 0.08, MWL decreased.

This study showed that by presenting simple BGM that was not specially composed, the user associated the name of its location (node) with the BGM, and because of this, was able to spatially differentiate it from other nodes, spatial cognition of the directory structure became easier, and learning effect increased.

However, this study had three BGMs, and the number is low. In a study of voice guidance in ATMs for visually-impaired people, when four or more items presented audio at the same time, test subjects could not answer correctly (Toyoda, 2016). This study only presented spoken language information, and hence, the information was in a format different from BGM; however, it demonstrates that it is necessary to take into consideration the amount of short-term memory required for processing auditory information. To this point, the possibility exists that even more BGM will be needed in a practical application, and it can be expected that when the number of simple melodies increases, the cognitive load for remembering the melodies will increase. One method for solving this problem in future is to express spatial information using music-like rules as in earcons, and add devices that help in adding nature sounds or sound effects to spur recall of item names. We would like to continue to study new methods for suppressing the cognitive load by making the directory hierarchy even easier to recognise.

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References

Blattner, M., Sumikawa, D. & Greenberg, R., 1989. Earcons and icons: Their structure and common design principles. Human Computer Interaction, 4, 1, 13.

Brewster, S.A. Raty, V.-P. & Kortekangas, A., 1996. Earcons as a Method of Providing Navigational Cues in a Menu Hierarchy. In Proceedings of HCI'96 (Imperial College, London, UK), Springer, 167–183.

Kramer, G. ed., 1994. Auditory Display. Addison Weslay, 6.

'Cybernavi', Pioneer Corp., http://pioneer.jp/carrozzeria/carnavi/cybernavi/avic-zh0999_line_avic-vh0999_line/interface/ (accessed in 24, January, 2016)

Kochi System Development: 'PC-Talker', http://www.aok-net.com/screenreader/ (accessed in 23, April, 2016)

Miyake, S. & Kumashiro, M., 1993. Subjective mental workload assessment technique: An introduction to NASA-TLX and SWAT and a proposal of simple scoring methods. The Japanese Journal of Ergonomics, 29, 6, 399–408.

Nagao, M., Ishida, H., Inagaki, Y., Tanaka, H., Tsujii, J., Tokoro, M., Nakata, I. & Yonezawa, A. ed., 1990. Encyclopedic Dictionary of Computer Science, Iwanami Shoten, Publishers., 15–38.

'NVDA', NV Access, http://www.nvaccess.org/ (accessed in 24, January, 2016)

Ohta, H., Nakajima, Y. & Kawamura, S., 1990. Processing Resources in Moving Picture Cognition. Departmental Bulletin Paper, Osaka Univ., 16, 155–180.

Sakayori, T. 2003. New Setting Method for Copy Machines for Visually impaired. Technical Report of IEICE WIT2002-77, 1–5.

Soma, Y., Matsunaga, T., Soga, J., Uchiyama, H. & Fukumoto, I., 2005. A basic study of human engineering on different music environment for work efficiency. IEICE Technical Report, 105, 304, 43–46.-NA

Toyoda, W., Shibata, H., Hiki, N., Hosono, N., Akatsu, Y. & Ohkura, M., 2016. Relationships between Memorability and Number of Items in Voice Guidance for Transactions in Talking Automatic Teller Machines. The Japanese Journal of Ergonomics, 52, 2, 71–80.

Yamanaka, K., Okada, Y., Kaneyoshi, A. & Iseki, O., 1997. A development of the tactile feedback device. Proceedings of the 1997 IEICE General Conference, 311.

Wickens, C. D., 1984. Processing Resources in Attention. In Raja Parasuraman and D.R. Davies (Eds), Varieties of Attention, New York: Academic Press., 63–102.