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# Interactive Evolutionary Computation Creating Congruent Media Content Composed of Different Media Types

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## Abstract

We use multiple media content every day, and using congruent media content composed of different media types is ideal for users. However, it is still difficult to obtain congruent media content. Interactive Evolutionary Computation (IEC) is a well-known method for obtaining good media content suited to each user's feelings as solutions to search problems. Conventional IECs were used for searching sole media type. This study proposes a new IEC that searches the congruent media content as a good combination of different types of media content. In the proposed IEC, the solution candidate contains variables corresponding to different media types. A system was constructed with a genetic algorithm, and it was used to investigate the efficiencies of the proposed IEC in the experiment. The target of creation was a relaxing set of music melody and scent. Twenty participants evaluated sets of music melodies and scents throughout ten generations in the search experiment. The experimental results showed a significant increase in the mean fitness and a significant decrease in the distance between solutions. No significant increase was observed in the maximum fitness values.

*Keywords:* congruent media content, Interactive Evolutionary Computation, music, scent

## 1 Introduction

In our daily life, we naturally use and enjoy media content. In many situations, different types of media content are used simultaneously. The most understandable example is a movie, which is a cross-modal content related to sight and hearing. Recent technologies enable us to enjoy complicated content composed of content pertaining to four senses [1][2], and using congruent media content each other is important to elicit synergy and higher effects on users. The effects and congruency of the different media types were focused on in terms of synergy effects and cross-modality in previous studies [3][4][5][6][7][8]. Using congruent media content composed of various media types will dedicate us to enjoy media content more and develop products having higher effects.

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How can users obtain congruent media content composed of different media types? Most of them were created by the technician or creator with their experiences. This fact means that special knowledge, skills, and feelings are demanded to obtain congruent media content. As another approach, trying all patterns of combinations, i.e., exhaustive search, is considered to be a candidate for finding congruent media content. However, the calculation of a large number of combination patterns is demanded.

Based on these backgrounds, this study proposes an efficient method to obtain congruent media content composed of different media types in terms of good combination. As an optimization method for media content, Interactive Evolutionary Computation (IEC) is known as a method of searching for good solutions suited to each user's feelings and preferences [9][10]. EC's stochastic search mechanism is a model of creatures' evolution process, and it is employed in IEC. Human users evaluate the solution candidates in IEC, while a mathematical function is used for an evaluation process in the general ECs. The IECs were applied to a variety of media types related to human senses [11][12][13][14][15][16]. However, the target of the conventional IECs was limited to sole media type.

The purpose of this study is to propose a new IEC that creates congruent media content composed of different media types. As an example, Fig. 1 shows a scheme of the proposed IEC that treats the content of music and scent as its solution candidate. The solution candidate has information about music and scent, and the user evaluates the set of them. Repeating this process will find a good solution in terms of a good combination of music and scent. Different sets of media types related to other senses can be implemented.

In this study, a concrete system is constructed to investigate the efficiency of the proposed IEC. The Genetic Algorithm (GA) [17][18] is employed as an evolutionary algorithm: therefore, this is an Interactive Genetic Algorithm (IGA) system creating music and scent. With the IGA system, we experimented the proposed IEC's fundamental effectiveness.

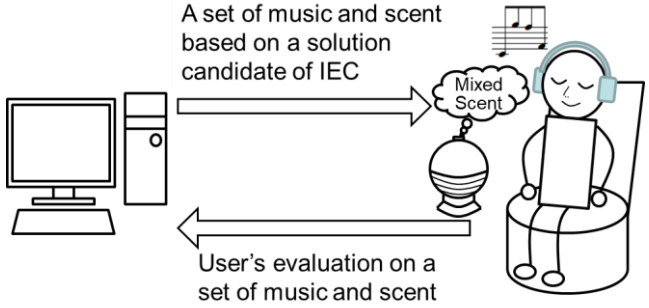



Figure 1: Interactive Evolutionary Computation creating congruent media content composed of different media types

## 2 Proposed Approach: Interactive Evolutionary Computation Creating Congruent Media Content

This paper proposes the IEC that creates congruent media content composed of different media types. This section explains the proposed IEC with descriptions of general IECs.

### 2.1 Interactive Evolutionary Computation

The general ECs search for good solutions based on models of the creatures' evolution processes. The search is performed with multiple solution candidates included in the population, and each

solution candidate has variables corresponding to the target of optimization. The most famous EC is GA, and GA is often used in IEC as its algorithm. A process of GA's search is composed of evaluation, selection of parents, and GA operations, including crossover and mutation processes.

With the EC's search ability, IEC finds good solutions for each user. In IEC, human users evaluate the solutions candidates by their subjective feelings. General user evaluation in IEC is done by scoring or selection, and obtained good solutions through the search are expected to suit each user's feelings. This point is the special property of IEC: obtaining good solutions suited to the user is difficult because the user's feelings are kind of black boxes that are a vague and unconscious mental model even for the users themselves. According to the survey of IEC [9], most of the targets were related to the senses of sight and hearing, e.g., the content of graphics, sound, and music. In rare cases, the senses of smell [11], touch [12], and taste [13][14] were also treated as the targets of IEC.

### 2.2 IEC creating media content composed of different media types

Various IECs were already proposed [10], and the application field became wider. However, no previous IEC study treating multi types of media content simultaneously was proposed. This study proposes a new IEC that creates congruent media content composed of different media types. From the viewpoint of cross-modality, using multiple types of media content congruent with each other effectively elicits users' feelings.

The IECs require the user to evaluate solution candidates for searching for good solutions. The proposed IEC presents different types of media content to the user at the same time. This means that the solution candidate in IEC has information on different types of media content, while the conventional IEC treats sole media type. Fig. 2 shows a solution candidate in an example of music and scent in the proposed IEC (Fig. 1). The solution candidate has eight variables divided into two parts: the music part and the scent part. The IEC's search with the solution candidates will find the congruent music and scent for each user.

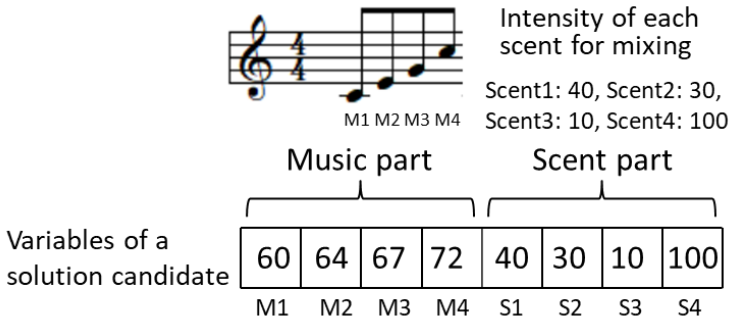



Figure 2: A relationship between the IEC solution candidate and music melody and composition of scent as an example of the proposed IEC

## 3 Experiment

The experiment was conducted to investigate the fundamental efficiencies of the proposed IEC. The experiment was performed with the approval of the Committee of Ethics in Human Research, Fukuoka Institute of Technology. The system of the proposed IEC was constructed based on IGA.

The target of creation was congruent music melody and scent for relaxation. A cross-modal effect of visual-hearing senses, such as the McGurk effect [3], is generally known, and the relation between hearing-smelling senses is also investigated in previous studies [4][5][6][7][8].

### 3.1 Experimental Procedure

Twenty persons (Ten females and ten males) participated in the experiment individually, and they evaluated the sets of music melody and scent afforded by the system. The experiment was performed in a quiet and ventilated room. Additionally, a deodorizer was set in the room. The participants were prohibited from intaking food and drinks except for water 30-min before the experiments.

By referring to the previous IEC studies [14][16], the experiment was composed of two steps: a search experiment with the IGA system and an evaluation experiment where the participants evaluated the representative IGA solution candidates (individuals) created in the search experiment. The participants could rest during the experiments freely and smell the coffee beans to refresh their olfactory fatigue.

In the search experiment, the participants inputted subjective evaluation related to "relaxing-stressing" feelings on each IGA individual to the system. The Semantic Differential method [19] with a 7-point scale was used as the evaluation scale on the set of music and scent: 1-point means "extremely stressed", 4-point means "neither", and 7-point means "extremely relaxed". For the participants who were not familiar with evaluating music and scent simultaneously, beforehand of the experiment, the experimenter explained to them to imagine that they were in both music therapy and aroma therapy.

The evaluations of IGA individuals in the search experiment were considered to be relative evaluations in each generation. Thus, in the evaluation experiment, the participants evaluated the two representative IGA individuals using a blind test to have a precise investigation. The evaluation experiment was performed after the search experiment on a different day. For each participant, the best IGA individuals were picked up from the 1st and the 10th generations in the search experiment. The set of music melody and scent related to the representative individuals were afforded to the participants at least two times, respectively. The order of presentation was randomized and counter-balanced, e.g., a sequence with set A, set B, set A, and set B. The same 7-point evaluation scale was used as the search experiment.

### 3.2 Setting of the Interactive Genetic Algorithm and Process of Affording Stimuli

The system used in the experiments was constructed based on the proposed IEC, and the IGA individuals' variables were integers. The variables in the music part corresponded to music keys by referring to the previous IEC studies [15][16]. The correspondence was defined by employing the rules of MIDI (Musical Instrument Digital Interface) format. The variables in the scent part were defined by the software of *Aromageur* [20]. These variables in the 1st generation were defined with random values.

Table I summarizes the details of the IGA system. Through ten generations, the participants were demanded to evaluate the IGA individuals 80 times at least. In the mutation process, the mutation necessary occurred in each IGA individual except the elite individual for creating a variety of IGA individuals, while the primary mutation ratio was 5% for each variable.

Fig. 3 shows the experimental settings used in both experiments. The participants listened to

music melodies during the experiments, and a noise-canceling function of the headphones (WH-1000XM3, Sony) was used in the listening. The mixed scent was created by *Aromageur* [20], which is an aroma diffuser mixing several aroma sources: the intensity of each aroma source is independently controlled via its exclusive software. *Aromageur* was used for affording scents to users in previous studies [11][21][22]. The created scents were transmitted to the participants by the weak wind. After listening to music melody and smelling scent, the participants input their evaluation via keyboard.

Each of the two stimuli was created with four variables, respectively (Fig. 2). In the music part, the variable corresponds to the key of the eighth note, and the music melody was played four times repeatedly, as shown in Fig. 4 (a). In this case, the variables in the music part were 60, 64, 67, and 72. The tempo was set at 60 bpm. Therefore, the time length of the melody was 8 s. In the creation of scent stimuli, four kinds of aroma oils were employed. As aroma sources, Lemon (S1), Vanilla (S2), Black pepper (S3), and Frankincense (S4) were selected by referring to a previous study, which investigated a relationship between sole odors and the pitch of music keys [4]. The participants did not know what kind of aroma oils were used in the experiments. The system started to afford these stimuli simultaneously to the participants, and the affordance of the scent was stopped in 4 s., half of the time length of the music piece (Fig. 4 (b)). This treatment was performed to reduce the participants' olfactory fatigue. The participants could repeatedly evaluate the set of the music melody and the scent corresponded to an IGA individual.

Table 1: Settings of IGA System

| Item | Details |
|---|---|
| Generation | 10 generations from the 1st to the 10th. |
| Number of IGA individuals in each generation | 8. |
| Number of variables in each IGA individual | 8. 4 for music part and 4 for scent part. |
| Range of variable | Variables in music part were related to music key from 60 to 79. Variables in scent part were related to the intensity of aroma source from 0 to 100. |
| Selection method in IGA | Tournament Selection and Elitism Strategy. |
| Crossover | 2-point crossover (95%). |
| Mutation | Variables in music part were changed in a range of 5: its probability was 5%. Variables in scent part were changed in a range of 30: its probability was 5%. |

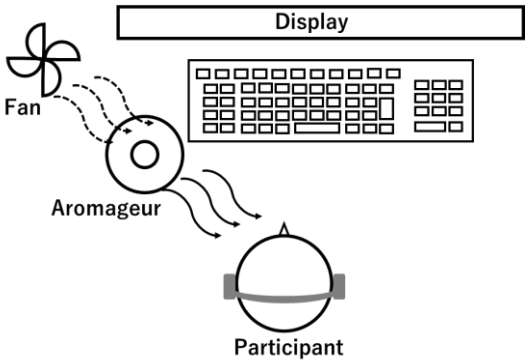
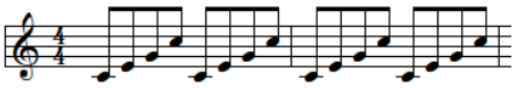
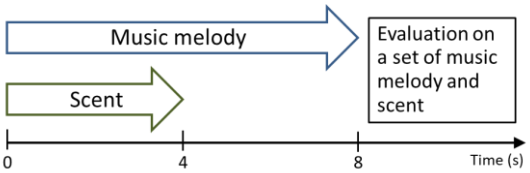



Figure 3: An experimental setting



(a) The music melody based on the four music notes included in the IGA individual




(b) The affordance of the stimuli and the participants' evaluation on the time scale

Figure 4: Creation of the music melody and time sequence of stimuli in the IGA system

# 4 Experimental Results

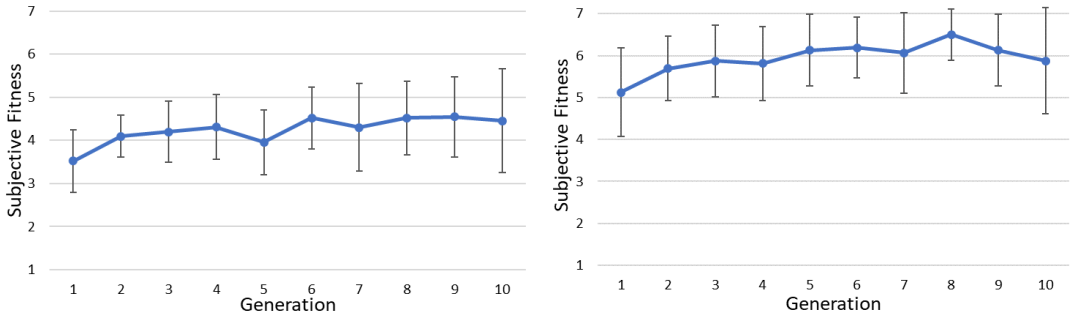
This section describes the results of the search and evaluation experiments. In the analysis, the fitness values progress and search space convergence were treated as indices. Wilcoxon's signed-rank test was used as the statistical analysis in the paired comparisons.

## 4.1 Results of the Search Experiment

Fig. 5 shows the progress of the mean and the maximum fitness values of all twenty participants. The error bars represent standard deviations. Gradual increases with small up-down were observed in both progress, and the highest fitness was observed in the 8th generation in the maximum fitness. The fitness values increased almost 1-point from the 1st to the 10 generations, respectively. The standard deviations were almost the same in all generations in both progressions of fitness values. As a result of the statistical comparison between fitness values in the 1st and the 10th generations, a significant increase was observed in the mean fitness value ($P$<0.05). The same comparison was performed in the maximum fitness values; however, no significant increase was found in the maximum fitness value ($P$=0.143). The mean elapsed time for the search experiment was 1178.9 s.

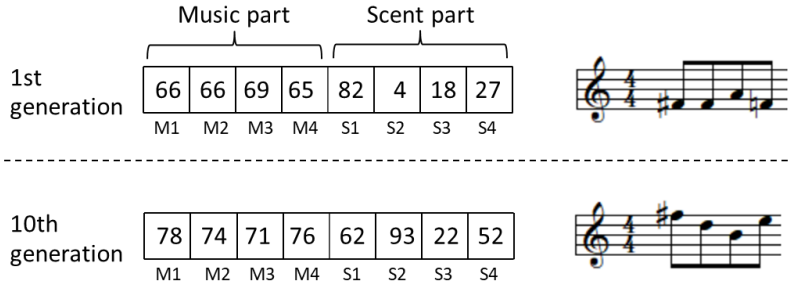
Fig. 6 shows the results of one participant in the search experiment. Fig. 6 (a) shows variables

of the best IGA individuals in the 1st and the 10th generation, respectively. There were no same values in each locus between them, and music scores were quite different. Fig. 6 (b) shows the progress of the mean value of IGA variables in each generation. The music and scent parts were divided into different graphs because their range was not same. Gradual increase and a larger change in the former half of 10 generations were observed in the key of the music part. In contrast, some variables gradually decreased in the scent part. In the progress of S2, the scent of Vanilla, rapid change was observed.

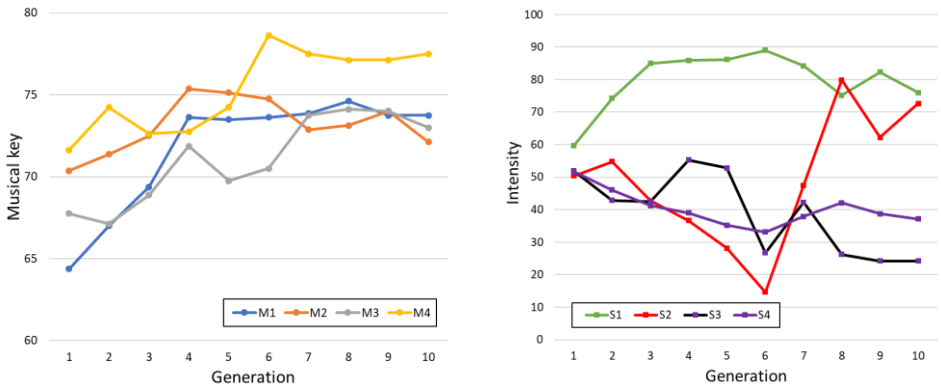



(a) Mean fitness (b) Maximum fitness

Figure 5: Progress of the mean and the maximum fitness values in the search experiment



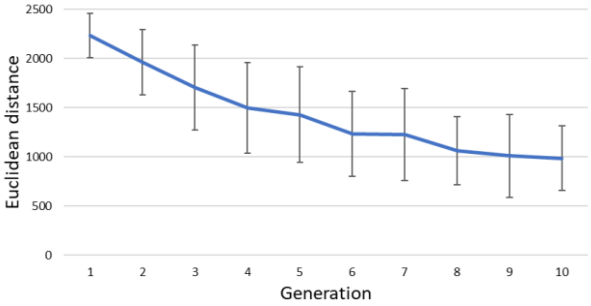

(a) The best IGA individuals in the 1st and 10th generations (Left: variables of IGA individuals, right: score of music part)



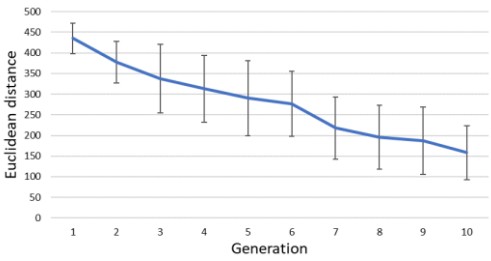

(b) Progress of the mean of each variable (Left: music part, Right: scent part)

Figure 6: Sample of results of one participant in the search experiment

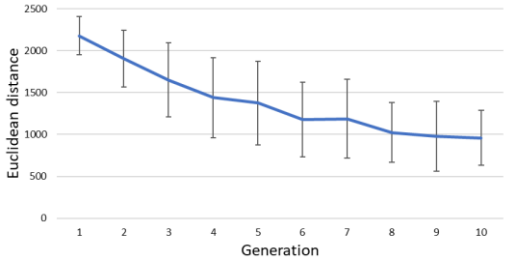
Fig. 7 shows progress of Euclidean distance between the eight IGA individuals. The distance is an index of convergence of the search, and an increase in the fitness and the search space's convergence were observed in the successful case of EC's search. The distance was a summation of Euclidean distances of 28 pairs (${}_8C_2$) of IGA individuals in each generation. Fig. 7 (a) shows the total distance obtained by eight variables, and it decreased linearly. Figs. 7 (b) and (c) were the distances of each music and scent part, and linear decreases were also observed. Around the final generations, the decrease in the music part continued, while the decrease in the scent part became slow down: between the 9th and 10th generations, the distance decreased in fifteen participants in the music part, and the decrease was observed in ten participants in the scent part.




(a) Total distance




(b) Distance of music part




(c) Distance of scent part

Figure 7: Progress of Euclidean distance of eight IGA individuals in each generation

## 4.2 Results of the Evaluation Experiment

Fig. 8 shows the subjective fitness values in the evaluation experiment. In this step, the participants evaluated the two best IGA individuals created in the search experiment. Fig. 6 (a) shows examples of the bests of one participant: this participant scored 3-point for the IGA individual in the 1st generation and 5-point for one in the 10th generation in the evaluation experiment. According to the mean values of all participants, the mean fitness value was higher in the 10th generation compared with the 1st generation. However, no significant difference in the statistical analysis was observed ($P$=0.182).

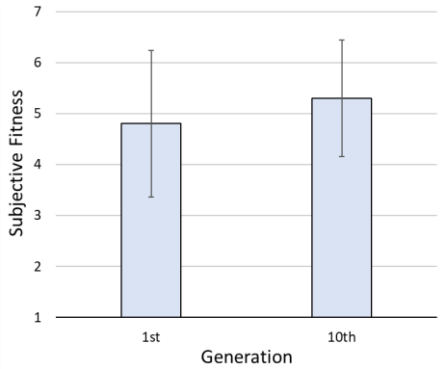



Figure 8: The fitness values in the evaluation experiment

# 5 Discussion

The result of the search experiment showed the statistical increase in the mean fitness. Furthermore, the obvious shrink of the search space was observed, although the mutation on the individuals must be occurred to have the variety of the individuals. The increase in the fitness and the convergence of the search space were often observed in the successful case of EC's search. Thus, these results showed the effectiveness of the proposed IEC in creating congruent media content in the case of music and scent as different types of media.

Meanwhile, the increases in fitness for the best individual in the search and the increase in fitness in the evaluation experiment were not significant. These results mean that the IGA system did not show enough search performance for the best individuals in the population, although the mean fitness increased obviously. With the results increasing mean fitness and shrinking the search space, the search was successful from the viewpoint of population level. In addition, with the result that the fitness of the best individual did not increase, the search might be trapped in local optima. Therefore, we should adjust the parameters of IGA and increase the number of individuals to avoid the local optima. Employing other evolutionary algorithms will also be a good solution for the improvement.

The search and evaluation experiments were performed on a different day, and this treatment aimed to perform a precise investigation of the efficiency of the proposed IEC with the evaluation experiment. Recent studies of olfactory suggested that the ability of human olfactory is not weak [23][24]: however, changes in the physiological condition might affect the participants' evaluation criteria. Performing the two steps of experiments on the same day may be appropriate for showing the fundamental effectiveness of the proposed IEC. Further investigation with a different experimental procedure is demanded with the improvement of the proposed IEC.

Related to the participants' evaluations, some participants commented to us that they felt difficulty in evaluating the music and scent as one set of stimuli after the experiment, while we did not formally gather the participants' comments on the music and scent stimuli and evaluation tasks. In other words, they evaluated the afforded music and scent separately, although the experimenter explained to them to imagine that they were in simultaneous therapies of music and aroma. In some daily situations, such as therapy and esthetic medications, we were afforded these stimuli simultaneously; however, we might not be familiar with evaluating the set of stimuli by scoring. We should investigate a more appropriate affording method for the set of stimuli so that the participants easily evaluate them as the set. Moreover, other sets of media content with different media types will be applied as the target of the proposed IEC.

Creating congruent media content is the main target of the proposed IEC. Moreover, discovering new knowledge from the obtained solutions is also essential, and this matter is explained as awareness by IEC's search [25]. By observing the shrink in the search spaces, the trend of decreases seems to be different between the music and scent parts: around the final generations, the decrease in the scent part was a little bit slow down. These results remind us of a new question: which is the essential media type for the user? In the future study, the congruency of two media types and dominance in their relationship will be analyzed after showing the significant increase in the best IGA individuals by the improved version of the proposed IEC.

# 6 Conclusions

This study proposed the new IEC that creates congruent content composed of different types of media. As a concrete system based on the proposed IEC, the system affording music piece and scent was constructed, and IGA was employed as an evolutionary algorithm. The system was used to investigate the effectiveness of the proposed IEC. The experiment was conducted with the target of creating a relaxing set of music and scent. The experimental results showed the significant increase in the mean fitness value in the search. In addition, the significant shrink of the search space was also observed. These results in the search experiment suggest the proposed IEC's efficiency in obtaining congruent content in the case of music and scent as different media types. However, in comparisons of the best IGA individuals, no significant increase was observed. Further studies are demanded with the improvement of the proposed IEC and experimental procedures.

In future studies, we should analyze the dependencies of variables for eliciting new knowledge from the obtained good solutions, a congruent media content. Moreover, the number of variables was eight in this study, and a larger number of variables is needed to create more complicated media content. The search based on the proposed IEC with other sets of different media types, e.g., senses of sight and hearing, is an attractive target for further study.

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