Generation of Creativity with Inspiration from Synaesthesia

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Keywords: Synaesthesia, Creativity, Generation, Inducers, Concurrents, Cluster, Five Sensory.

Abstract: The key to creativity does not lie solely in the mental process. It is also regarded as a cultural or social activity. Methods of supporting creative ideas generation have been studied and researched widely in various domains. Among such studies, Gerald has summarized 172 methods that can be applied to creative ideas generation. Although his research has covered the most used strategies, yet, synaesthesia as an incredible phenomenon in which the stimulus arouses one or more additional sensory experiences has never been adopted as a strategy to generate ideas. The aim of this research is to support creative ideas generation by merging computers and synaesthetic experiences. Hence, a visual-related synesthesia-based creativity support system is proposed to support creative ideas generation. Initially, synaesthesia is divided into synaesthesia clusters composed of five sensory stimuli (e.g., visual-visual, visual-auditory) by analyzing synaesthetic experiences recorded in various literature. Then, synaesthesia clusters related to vision were selected as the most prevalent synaesthetic experience to generate a variety of rules. As a result, various rules are fused to produce numerous imaginative elements for people to select, thus promoting the human imagination, and supporting creative ideas.

1 INTRODUCTION

Creativity is more than just a mental process; it is also a cultural and social activity (Vidal 2009). In general, creativity is defined and evaluated in a variety of ways. For example, in terms of evaluation, Boden considered that creativity is the ability to generate "new, surprising, and valuable" ideas or artifacts (Boden 2007). Meanwhile, Stein et al. believed that creative work is a new work acknowledged by a community as tenable, useful, or pleasurable at some point in time (Stein 1953). Generally speaking, creativity should simultaneously fulfill the new, valuable, and acceptable criteria in most cases.

The existing research proposed various techniques to achieve the criteria mentioned above. For instance, Boden proposed the most widely accepted and classic technique in 2004: creativity can be acquired in three forms based on categorical characteristics: combinational, exploratory, and transformational (Boden 2004). It is easy to find various creative support systems that employ a variety of ways to aid in gathering relevant data and the creation of ideas (Wang and Nickerson 2019). The necessary and prerequisite condition for generating creativity is the generation of creative ideas, which have been the focus of creativity research. As early as 1998, Gerald studied 172 proposed approaches to idea generation and summarized three positive elements for generating creativity: strategies, tactics, and enables, the latter two aimed at promoting the first (Smith 1998). Specifically, methods such as idea generation, brainstorming (Potter and Balthazard 2004), and mind mapping (Massetti 1996) are still popular at present. Some studies employ a visual technique to present stimuli to stimulate new ideas (Wang, Cosley, and Fussell 2010; Wang, Fussell, and

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Zeng, C., Zhou, J., Lu, Z., Wu, Y., Nie, Z. and Yang, H.
Generation of Creativity with Inspiration from Synaesthesia.
DOI: 10.5220/0011916000003613
In *Proceedings of the 2nd International Conference on New Media Development and Modernized Education (NMDME 2022)*, pages 560-570
ISBN: 978-989-758-630-9

Cosley 2011).

Synaesthesia is an incredible phenomenon in which the stimulus arouses one or more additional sensory experiences (Grossenbacher and Lovelace 2001). It is worth noting that synaesthesia plays a critical role in the development of sensory products, and user-specific experiences can be obtained through the imagination and creativity generated by multiple sensory modes (Merter 2017).

Creative support systems are a typical tool for enhancing human creativity through stimulating and documenting the creative process and are often used to stimulate the creative potential of individuals and groups (Massetti 1996; Wang and Nickerson 2017).

2 RELATED WORKS

In recent years, synesthesia researchers have tended to invest in the relationship between different types of synesthesia, like how different types of synesthesia fit together (Ward and Simner 2021)? The relationship between different synaesthesia forms and their ability to participate in art or creativity (Lunke and Meier 2019). Especially, researchers studied the effects of synesthesia on letter representation in different languages, not only English-speaking (Root et al. 2021). In addition, researchers also believe that synaesthetes are more creative than non-synesthetes due to the difficult concepts that can be perceived (Mulvenna et al. 2003). Others consider that creativity and the processing information ability can be improved by activating more of the sense of non-synesthetes (Merter 2017).

Some researchers considered that stimulus relatedness is positively related to the idea quantity and idea usefulness. Their study indicates that remotely related stimuli, not unrelated stimuli, tend to improve idea novelty. Such as the Wikipedia-based approach to support creative idea generation (Wang and Nickerson 2019). Others developed a computational tool using a combination of ontology and analogy to assist designers in generating creative ideas in the early stages of design (Han et al. 2018).

3 METHODS AND PROCEDURES

This study designed creative ideas support system that inputs visual, auditory, and gustatory, and randomly outputs pictures with shapes, numbers, and colors through analyzing synaesthetic experience, constructing rules between inducers and concurrents, and summarizing and generalizing the rules. The specific steps are as follows.

3.1 The Regular Conceptual Space Recognition

It requires breaking the regular rules to achieve novel and surprising results. Therefore, the first step is to figure out the typical components of the regular ideas. The standard components could be considered as the rules constituting the conceptual space of the specific meaning, themes or topics. For instance, if the users aim to convey the meaning of cheerfulness, the standard visual components might be the beers, people's smiles and colourful background. To achieve novelty, the typical components could be replaced with other untypical components that are remotely relevant. In this case, synaesthesia experience would be helpful to find out the corresponding components remotely relevant to the typical components. We can consider standard components as the inducers and unregular components as the concurrences. The following steps describe the process of matching inducers with concurrences.

3.2 Classification of Synaesthesia Types

Many researchers have extensively studied and applied different classification methods for the various synaesthesia forms: period-based (neonatal and adulthood synaesthesia), timeliness-based (momentary and permanent synaesthesia), function-based (strong and weak synaesthesia) (Rogowska 2011), and so on. The following steps will be applied to classify synaesthesia types:

Synaesthesia Clusters Adopted As the results of studies indicate, 61 different forms of synaesthesia have been recognized as of 2010 (Day 2016), and by 2022, 164 forms of synaesthesia have been documented (Ward and Simner 2021). Furthermore, researchers are frequently accustomed to defining synaesthesia types through paring inducer and concurrent (inducer-concurrent synaesthesia) (Ward and Simner 2021), such as “grapheme-color synaesthesia” implies letters or numbers evoke an unusual color. This method of synaesthesia definition based on synaesthetic phenomena is intuitive but also leads to an overwhelming variety of types and a lack of essential representation. Accordingly, some methods named “synaesthesia clusters” have been adopted by several researchers to generalize and represent a group of related synaesthesia types (Novich, Cheng, and Eagleman 2011; Ward and Simner 2021). It is notable that Ward et al. classified synaesthesia clusters in terms of common "concurrents" rather than common "inducers” and selected 112 possible synaesthesia types for cluster categorization after a comprehensive assessment of 164 synaesthesia types, ultimately summarizing eight synaesthesia clusters and ranking their prevalence (which will be utilized in my following software design) (Ward and Simner 2021). In this classification model, the synaesthesia clusters approach is also employed in the classification of synaesthesia forms, and unlike the approach proposed by Ward et al., a common 'inducer' will be applied as the aggregated instead of a common 'concurrent'.

Intra- and Inter-modal Relationship One possible way to elucidate the process of synesthesia phenomena is widening the concepts of intra- and inter-modality processes proposed by Marks (Marks and Odgaard 2005). Specifically, Intramodal synaesthesia signifies that the inducers and concurrents being generated in the same modality, e.g., seeing colors when seeing black numbers (Rich, Bradshaw, and Mattingley 2005), whereas Intermodal synaesthesia refers to inducers and concurrents arising in different modalities, e.g., seeing images when hearing sounds (Baron-Cohen, Wyke, and Binnie 1987). Regarding the previously mentioned synaesthetic experience as one sensory stimulus eliciting one or more sensory stimuli, intermodal synaesthesia can be split into one-to-one and one-to-many (multimodal), but the latter scarcely exists and is excluded from discussion in this model

Five Sensory Modalities As mentioned earlier, synaesthesia is evoked by sensory modalities. Specifically, a wide variety of synaesthetic experiences or phenomena are gained through five human senses - visual, auditory, tactile, gustatory, and olfactory. Accordingly, five sensory modalities can be employed as both inputs to the inducers and output to the concurrence in this categorization model. 25 synaesthesia clusters were acquired through arranging and combining the inputs and outputs based on one-to-one modality: visual-visual (visual to visual and the inducers in front), visual-auditory, auditory-visual, and so on.

In 2011, some researchers pointed out that ninety-eight percent of the tens of thousands of individuals reported synaesthetic experiences were activated by stimuli such as letters, numerals, or words (Novich et al. 2011). That is, synaesthesia evoked by visual stimuli predominates, which coincides with the finding in 2022 that concurrents triggered by visual stimuli were the most common through an investigation of 164 possible synaesthesia types in 2925 self-referred synaesthetes (Ward and Simner 2021). Thus, the visual-related synaesthesia clusters are the focus of the Synaesthesia Classification Model, which contains nine visual-related synaesthesia clusters, namely visual-visual, visual-auditory, visual-tactile, visual-gustatory, visual-olfactory, auditory-visual, tactile-visual, gustatory-visual, and olfactory-visual. Furthermore, some researchers have asserted that intramodal synaesthesia plays a meaningless role in synaesthesia classification (Jackson and Sandramouli 2012; Novich et al. 2011; Ward and Simner 2021). Figure 1 shows the visual-related one-to-one synaesthesia modality that will be discussed in this system.

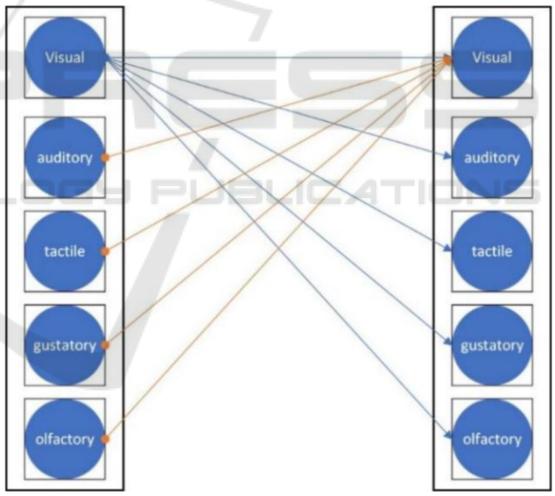


Figure 1: visual-related one-to-one synaesthesia modality

3.3 Rules Construction

In this system, the construction of rules is derived from the summarization and induction of various synaesthetic experiences, each corresponding to a synaesthetic experience. Specifically, the inability of ordinary people (non-synaesthetes) to feel, experience, or even imagine the spontaneously generated synaesthesia concurrents when a stimulus occurs can, to a certain extent, restrict the imagination or association of people, and hinder the support of creativity. An effective way to overcome this limitation is to use the rules provided by this system to help people imagine or associate with more "infinite possibilities". In addition, it is also interesting to note that researchers are keen to focus on the meaning of stimuli (inducer) (Boden 2007), the effect of stimuli (Cytowic 2002), while the effect or meaning of stimulus production (concurrents) has been ignored. However, the rules are a mapping of stimulus to the outcome, i.e., the inducer-concurrents, which not only responds to the effects of the inducers but also the concurrents, and it corresponds to the whole process of computer input and output, so the rules provided by this system can effectively help people to come up with more creative ideas.

Table 1 detail the rules generated by inducting and summarizing the various synesthetic experiences documented in the literature. It can be seen that most rules are generated by visual-visual clusters, followed by auditory-visual. In addition, the most prevalent concurrents are color and shapes. It is worth noting that the same inducers can arouse different concurrents, meanwhile, the same concurrents can be stimulated by different inducers. In all, these features provide strong support for the design of our systems.

Table 1: Rules based on synaesthesia clusters

Synaesthesia clusters	Rules
Visual-visual	(1) Visual or visual motion triggering evokes color perception ● Inducers: letters, shapes, numbers, swimming style, time units (months, years, weekdays), numerous sequence units (shoe sizes, height, TV stations, body temperatures), name. ● Concurrents: color (red, green, yellow, etc,) (2) Visual triggering evokes space perception ● Inducers: letters, numbers, time units, numerous sequence units. ● Concurrents: shapes (circle, oval, ellipse, diamond, star, etc.), three-dimensional shapes, spatial arrangement (columns, spirals.) (3) Visual triggering evoke parity ● Inducers: letters, numbers, time units, shapes, words. ● Concurrents: feelings of oddness and evenness. (4) Visual triggering evokes personalities ● Inducers: letters, numbers, simple shapes, and even furniture. ● Concurrents: rich and detailed personalities
Visual-auditory	((1) Visual motion induces auditory ● Inducers: non-moving visual flashes, continuous visual motion ● Concurrents: non-linguistic sounds (such as beeping, tapping, or whirring), pitches, chords
Visual-tactile	(1) Visual or imaginary triggering evokes physical touch sensation ● Inducers: others touch, pain ● Concurrents: physical touch (pain) (2) Visual evoke touches ● Inducers: words, people names, numbers, letters, days, months ● Concurrents: touch
Visual-gustatory	(1) visual triggering evokes tastes: ● Induces: food, playing music words ● Concurrents: emotional valence tastes (unpleasant, neutral, very pleasant tastes), food flavor, shapes
Visual-olfactory	(1) Visual triggering evokes smells ● Induces: words, Playing music, Months, Peoples names ● Concurrents: flavors
Auditory-visual	(1) Auditory sensations evoke color imagery ● Induces: Hearing words, Voices of different pitch, particular piano note, a tone at 2000 Hz, absolute pitch, being spoken to, complex jarring sounds ● Concurrents: colors (dynamic, the color deepens as the pitch rises and decreases as the pitch decreases)

	(2) Spoken or tone evoke words ● Inducers: tone, being spoken to ● Concurrents: words, reproduction out of the mouth (like ticker taper) (2) Sounds evoke shapes or numbers ● Inducers: sounds ● concurrents: shapes (dynamic random dots, square, circles), numbers (0,100, 400)
Tactile-visual	(1) Tactile stimuli evoke visual motion ● Inducers: tactile ● Concurrents: visual sensation (movement, expansion, jumping) (2) Tactile stimuli evoke color ● Inducers: touch, thinking about touching ● Concurrents: color
Gustatory-visual	(1) Taste evokes shapes: ● Inducers: food taste ● Concurrents: geometric shapes appear to morph over time (e.g., from pointed to round) as the taste develops on the tongue (2) Taste evokes colors: ● Inducers: food taste ● Concurrents: colors
Olfactory-visual	(1) Smell evokes shapes: ● Inducers: food smell ● Concurrents: geometric shapes

4 A CREATIVE IDEA GENRATION SYSTEM

According to the construction of the previously mentioned rules, the mapping of inducer and concurrents are shown in Figure 2 through summarizing and generalizing. Among them, the red circle represents concurrents, and the blue one represents inducer. Thus, a creative idea support system consists of inducer and concurrents, creative idea support through different search conditions. There are two kinds of search ways:

Concurrents-inducer Concurrents are entered into the system as a search condition, and can then be output to display various inducers, followed by the selection of one of the inducers to eject its properties. For example, the user wants to find the colors generated under various visual influences, “color” as concurrents can be entered into the search box, then inducers: “grapheme”, “swimming style”, “sequence number” will be demonstrated, followed by clicking on one of the inducers “swimming style”, the properties can be output and displayed "butterfly", “breaststroke”, “freestyle”, etc.

Inducer-Concurrents The inducer is entered into the system as a search condition, the system then selects the various matching concurrents. For instance, “shapes” as inducer can be entered into the search box, then concurrents such as “color”, “3D shapes”, “parity”. will be displayed, followed by kinds of properties.

4.1 System Implementation

Under current circumstances, the search technique of inducer-concurrents is adopted in the creative idea support system.

Input According to the previously generated synaesthesia rules, the system input architecture derived from the inducers is composed as shown in Figure 2. In particular, the input architecture consists of visual, auditory, and gustatory. Specifically, the visual input selects English words, numbers, and swimming postures; the auditory input selects sounds and piano notes; the auditory selects food flavors. In particular, the four special swimming styles can trigger color vision in an intuitive picture selection mode; the selection of sounds adopts the form of a click-to-play to enable the users to hear a certain sound; the food flavors are selected by clicking on one of the taste sensations (sour, sweet, bitter, spicy and salty). Screenshots of the system of showing each of the three sensory input are shown in Figure 3.

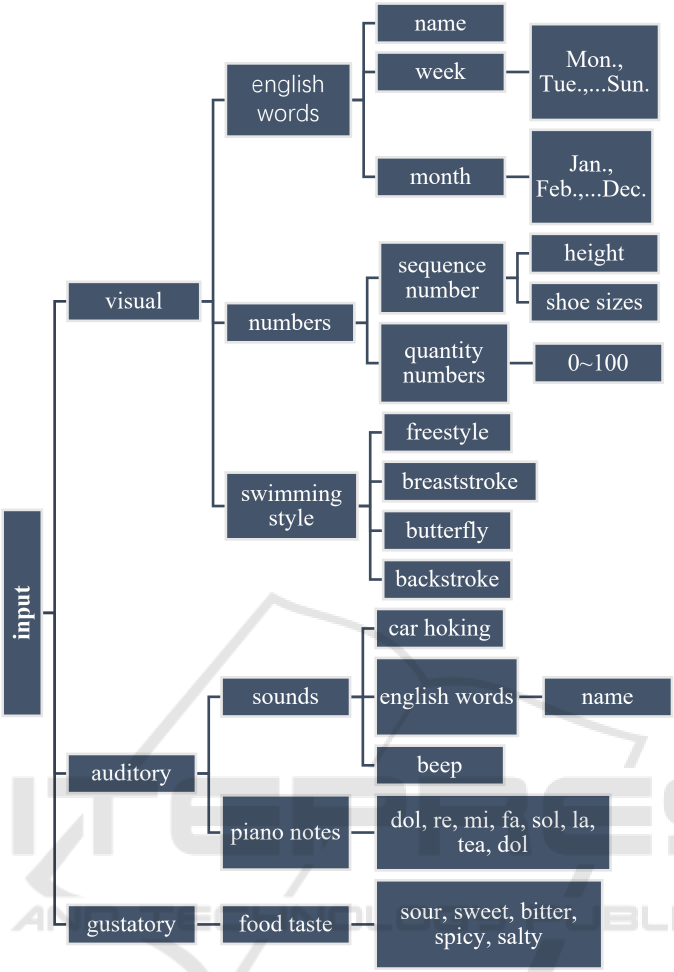
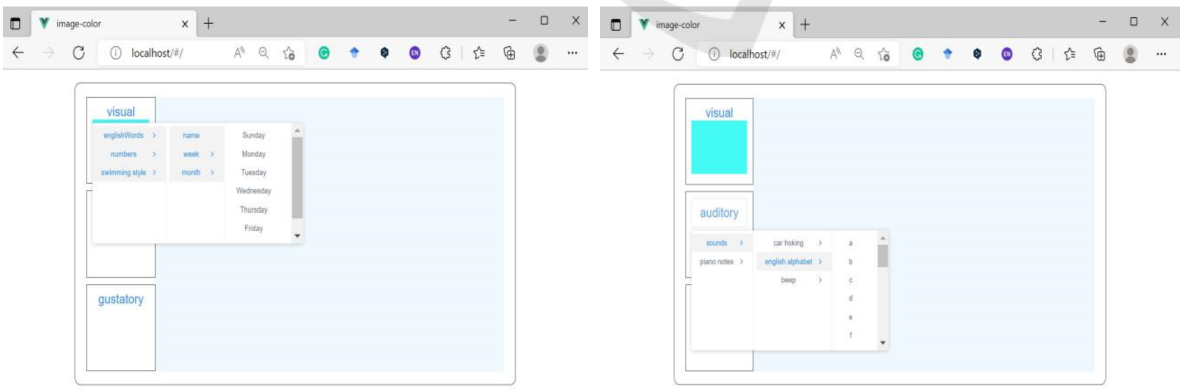
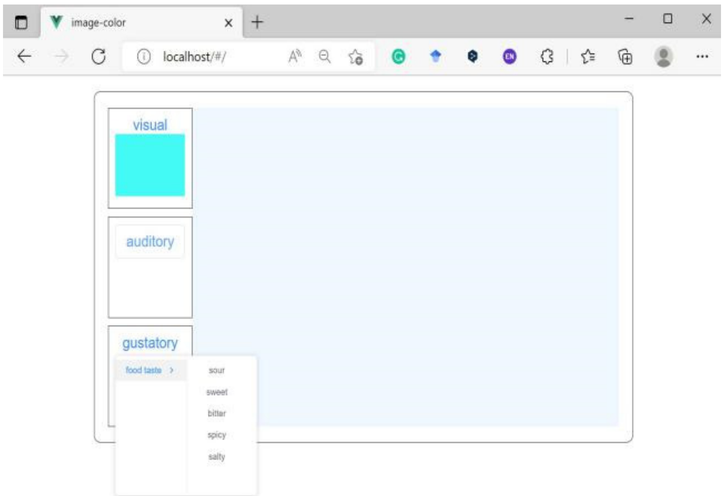


Figure 2: Input architecture of the system



(a) (b)



(c)

Figure 3: (a) the visual input of the system. (b) the auditory input of the system. (c) the gustatory input of the system

Output Similarly, the system output architecture is based on the concurrents of the synaesthesia rules, as shown in Figure 4. Three common concurrents (shapes, numbers, and colors) are selected to form the output picture. Specifically, colors are randomly generated through visual input which contains twelve colors (red, orange, yellow, etc.); shapes consist of four types (animal, geometry, item, and botanical) which can be randomly selected by auditory input; numbers are randomly generated from 0 to 10 to determine the number of shapes. Accordingly, the final display is a fusion of three elements (shapes, color, number) of visual output, where the color and quantity of shapes are determined by visual and gustatory inputs, respectively. For instance, "Eight Blue Bottles" will appear on the screen after input, as shown in Figure 5. It is worth noting that each input will trigger a different output.

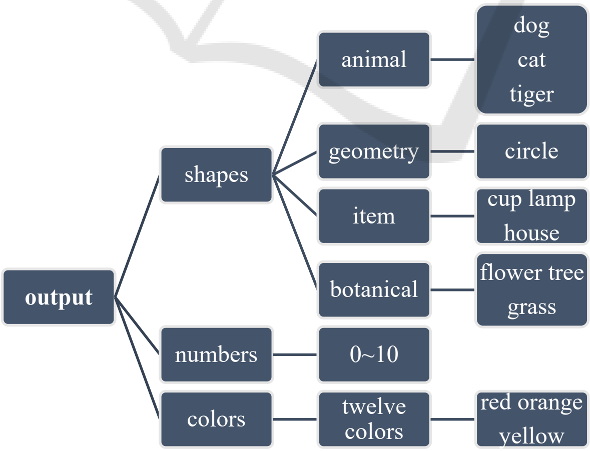


Figure 4: Output architecture of the system

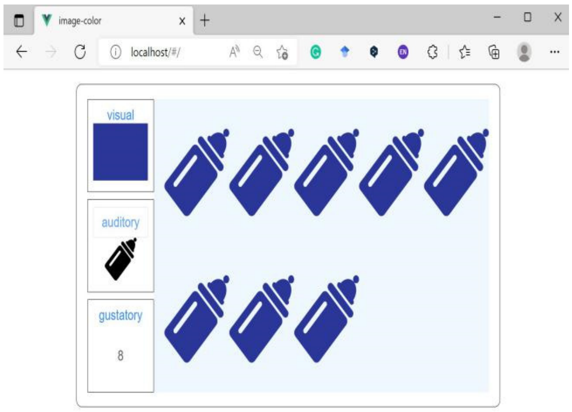


Figure 5: Output of the system

5 SYSTEM VALIDATION

The various matching rules of the system come from the various types of synaesthesia recorded in Table 2. For example, the swimming style that arouses people to perceive color is the swimming style synaesthesia type; the piano notes that elicit people to perceive shapes belong to the colored-hearing synaesthesia type; food tasting that arouses people to perceive numbers is the smell-shapes synaesthesia type. In particular, English words that cause people to perceive color belong to grapheme-color synaesthesia - the most common form of synaesthesia. In addition, swimming style synaesthesia. Sequence-space synaesthesia are classified as visual-visual clusters due to the colors, letters, numbers, swimming style, time units (months, years, weekdays), etc. are all perceived visually.

Table 2 visual-related synaesthesia types

Synaesthesia clusters	Synaesthesia types
Visual-visual	(1) Grapheme-color synaesthesia (Root et al. 2021; Simner and Bain 2013) (2) Swimming style synaesthesia (Mroczko-Wąsowicz and Werning 2012; Nikolić et al. 2011) (3) Sequence-space synaesthesia (Price and Mentzoni 2008; Sagiv et al. 2006; Smilek et al. 2007a) (4) Stimulus-parity synaesthesia (Dumbalska et al. 2017) (5)Ordinal linguistic personification (OLP) (Simner and Holenstein 2007; Smilek et al. 2007b)
Visual-auditory	(1) Visual-auditory synaesthesia (Noble et al. 2010) (2) Hearing-motion synaesthesia (Rothen et al. 2017; Saenz and Koch 2008)
Visual-tactile	(1) Mirror-touch synaesthesia (MTS) (Banissy et al. 2009; Banissy and Ward 2007; Ward, Schnakenberg, and Banissy 2018) (2) Language-touch (Ward and Simner 2021)
Visual-gustatory	(1) Lexical-gustatory synaesthesia (Cytowic 2003; Ward and Simner 2003)
Visual-olfactory	(1) Lexical-smell synaesthesia (Cytowic 2002; Ward and Simner 2021)
Auditory-visual	(1) Colored-hearing synaesthesia (Baron-Cohen et al. 1987; Jäncke and Langer 2011; Lorusso and Porro 2010) (2) Auditory-visual synaesthesia (Chun and Hupé 2013; Jackson and Sandramouli 2012) (3) Lexical-gustatory synaesthesia (Luria 1987) (4) Ticker taper synaesthesia (Chun and Hupé 2013)
Tactile-visual	(1) Touch-vision synaesthesia (Armel and Ramachandran 1999) (2) Touch-color synaesthesia (Simner and Ludwig 2012)
Gustatory-visual	(1) Taste-shapes synaesthesia (Cytowic 2003; Downey 1911)
Olfactory-visual	(1) Smell-shapes (Cytowic 2003; Cytowic and Wood 1982)

6 CONCLUSIONS

We propose a creative support system that generates creative ideas that can effectively broaden the mind and provide more clues or ideas for human association and imagination. It is worth noting that whereas past approaches have chosen "concurrents" as the synaesthesia classification. We adopt "inducers" as the common classification. Synaesthesia clusters formed on the basis of the five senses (visual, auditory, tactile, gustatory, and olfactory) essentially encompasses all synaesthetic phenomena except for those related to emotions. In addition, selected visual-related synaesthesia clusters do not include about 1% of the synaesthetic experiences, so the system basically reflects the majority of the synaesthetic experiences. We discover the mapping relationship between inducers and concurrents through the analysis of synaesthesia rules, which led to a more systematic approach to creative idea support.

Furthermore, visual-related synaesthesia clusters can also be expanded into related with auditory, tactile, etc., so that the system can be classified according to different sensory clusters, allowing for a wide range of applications, especially in the creation of human poetry, rhetoric, fiction, etc. enhancing the richness of imagination or association elements and cues. The system does not list all the properties of the inducer, but only some basic properties, such as "shape" only lists "rectangle, triangle, circle", so in the future, the system can be improved by increasing the properties dictionary. Creative support systems can be applied to in assorted working domains such as knowledge management, programming and music production. Although such domains have different focus, but the principles and the major elements have similar features behind corresponding creative support system (Hewett 2005).

In all, the diversity of creative ideas generation methods is broad and abundant. But it is still very new and rare to involve synesthesia in such domains. Accordingly, it is believed that it is beneficial to consider synesthesia's nature and mechanism as a potential approach to stimulate more creative ideas.

ACKNOWLEDGEMENTS

First and foremost, I would like to give my deep and sincere gratitude to this research's advisor Prof. Hongji Yang, for providing invaluable guidance throughout this research. Besides my advisor, I would like to thank Zhongxi for providing the analysis of the creative support system and Yue's effort on designing the interface of the proposed system. My warmest thank also goes to Zicheng, for his insights into the relationship between synaesthesia and creativity. Thank you again, for supporting this research.

This work was supported by "Research on people's livelihood-oriented urban planning and management in Jinlin Province, No. 2020 0101058FG", and "Cloud-based urban visualization integrated management platform based on big data and knowledge system, No. 20210203146SF".

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