

COL.diesis: transforming colour into melody and implementing the result in a colour sensor device

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Abstract

This paper represents a system which explores the reality of colour in relation to sound and dedicated firstly to blind people, the challenges they live with, their psychology and their emotions. It's an exploration of the infinite range of colours that they have either never been able to see or that they have lost the possibility to see. The system developed is based on the concept of synesthesia: a 'liaison' between colour and sound, colour that becomes sound.

This paper synthesizes a wider range of study regarding people with diverse psychological and movement conditions. It represents a new method of expression and of self development through music therapy and game, dedicated mainly to children aged between 5 and 13.

Finally we conclude with a portable prototype device that has been validated and patented. It is capable of detecting colour and transforming it into sound: a colour sensor identifies colours and transforms this data into musical notes. The prototype is totally adaptable to the requirements of the end user meaning that the user can choose the best combination between colour and sound in order to improve their communication with the environment. We are now developing a mathematical theoretical background in order to formalize the correspondence between colour and musical space.

*Keywords*_colour, sound, music, blind, vision, disability, synesthesia, device

1. Introduction

Colour represents one of the most important and conditioning aspects of the reality that surrounds us. It has the great capability of moving us, impressing us and of creating meanings and symbolic values which, consequently, play a part in the culture and traditions of each one of us.

In general colour isn't perceived uniquely through our eyes but also thanks to other aspects of a cultural type, through our conscience and subconscious. Aspects like

primordial images, symbolism, cultural influences and traditions as well as personal experiences all form part of our singular and personal way of perceiving colour.

Colour is associated to feelings and basic life concepts such as romance, tranquility, hate, happiness, sadness, etc. as concluded by the many studies that have been made on the subject: the symbolism which belongs to colour walks hand in hand with common imagination [1]. Colour, associated with either hearing or touch, represents one of the most common combinations in this field. Colour is connected to other senses besides sight.

Blind people create concepts based on their personal experience and according to their point of view and imagination. They associate descriptive words and every day conversation to feelings, things they read, tactile experiences, hearing, taste and smell. Just because a blind person cannot 'see' colour, this does not take away from the fact that they can interpret it in their own personal way [2].

COL.diesis is a device capable of detecting colours and transforming them into musical notes or melodies inspired by the concept of synesthesia which plays a fundamental role in the whole of the project [3].

COL.diesis represents an innovative study from a theoretical and technological point of view and it includes all the important ingredients in a proposal of social credibility as it encloses a wide range of problematic situations and disabilities. It counts on an important technological component, with the programming of the software of the device and the modeling of an original colour/sound concept.

2. Brief state of the art

This project works towards the creation of a game useful for psycho-pedagogical development in children through music and colour. Its principal objective is to help its target user-group to interact with their surroundings. Among the precursors in the field, Steven Megan and Blakemore Colin during their study 'Visual synesthesia in the blind' research on colour perception in the case of blind people [4]. Another interesting basis is given by the See ColOR project by Guido Bologna, Benoit Deville,

Thierry Pun, and Michel Vinckenbosch where the goal of the project was to achieve a non-invasive mobility aid for blind users that would use the auditory pathway to represent in real-time frontal image scenes [5]. The main difference being that COL.diesis' objective is to create a mobile bracelet that not only would be non-invasive but also a portable device. Closer to COL.diesis is Neil Harbisson, a colour blind artist who is working on a portable device that similarly reproduces music according to colour [6]. Col.diesis aims to design a didactic game for children and this is where the need to simplify the melodies causes diversity between these two projects. More information is available in the biography.

3. Theoretical background

The project is based on three years of theoretical investigation and practical research.

Firstly a multi-subject investigation on a psycho-pedagogical level was worked on. Its principal themes being colour and music, synesthesia, music therapy and colour perception for the blind.

3.1 Synesthesia

The main characteristic of synesthesia is that of provoking, through stimuli of one specific sense, perceptions that come from other senses. For example the sound that is produced by musical instruments (hearing) can cause perception of colour (sight). We may conclude that synesthesia recognizes senses as elements that cooperate with one another.

Synesthesia manifests itself at different levels, its purest form being very rare. Nevertheless in all people we can find the synesthetic capability, more or less present, of perceiving at a cognitive level: capability which is often conditioned by culture and teachings or daily experiences [7].

3.2 Music and Music Therapy

On a sensorial level, music can help the blind develop to their auditory perception, teaching them to base it on a sequence of sounds. In addition, in physical exercises, music helps develop a sense of space.

Musically, it is very important to allow a child who has visual difficulties or other psychological or physical conditions to discover as many sounds as possible:

- Encouraging them to listen to sounds through different approaches (working with their imagination, concentrating on effects and barely perceivable changes in sound, etc.);
- It teaches to learn various positions and change in gestures in order to obtain distinct sounds;
- It allows them to create their own exercises and games so that they can appreciate personally chosen sounds, analyse them, learn to recognise them and differentiate them [8].

4. Prototype system implementation

The investigation team carried out an analysis on how to build the proposed device COL.diesis, whose

main objective on a technological level is to detect colour and transform this data into musical notes following a recognizable scheme. This work can be divided into two sections:

- a) The electronic component: through a colour sensor the device can detect colour and recognise it's RGB values;
- b) The software component: colours are

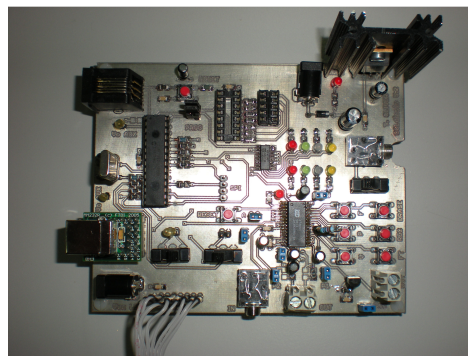


Figure 1 Prototype of the electronic components of the COL.diesis device

classified in groups which, once programmed in the device, permit an easy access to the available options and the simple recognition of colour through music.

The COL.diesis device is composed of two main components: a ring and a bracelet. It has been designed in order to cover aspects of ergonomics, lightness and straight forward usability.

The bracelet is characterized by a colour sensor that detects colour interpreting its RGB value and redirecting this number to the battery of sounds. Each colour corresponds to a specific sound: once recognized, the device has the capability off reproducing it so that the user can hear it. In other words the device is formed by a colour sensor and detection system, and a sound reproduction system.

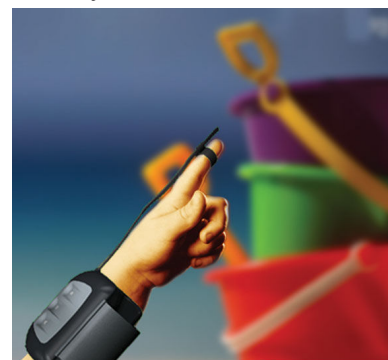


Figure 2 Representation of the COL.diesis bracelet

COL.diesis is small, ergonomic and light, guaranteeing easy transportation. It is considered essential for some of the objectives of this project that the user can move freely whether they are in a closed environment or outdoors.

It will be supplied with headphones that allow isolation should a game require it or if the user would like to colour/sound experiment on their own. They are also useful during the programming of the device.

COL.diesis is characterized by a colour sensor. The system will be comprised of an electronic component, necessary for the recognition of the signal so that it can be interpreted by the intelligent unit of the system. The system control component will be formed by a microcontroller PIC. Once the colour has been identified, a musical file will then be associated to it and the resulting sounds will be attained through an electronic device.

The device has been patented.

5. Experiments

5.1 Colour/Music

The COL.diesis team worked on a colour/music code with the clear objective to create a group of short melodies that could represent colours following the general rules of colour psychology. Most people interpret colours thanks to common concepts, historical and cultural ideas that can be transferred onto a sound, a melody and subsequently related to colour. Working with the help of music composers and through a series of tests a group of melodies was finally created.

The tests were run through internet trials or directly with children. In the first case the melodies were uploaded to the internet and 700 people were contacted and asked to run the test, the results being very satisfying.

In the second case the tests were proposed by being in direct contact with children from schools, asked to listen to the melodies played and to name a colour.

Children with visual impairment and other disabilities like Down syndrome were also contacted. In the first case the choices made were very similar to the results achieved with sighted people.

When choosing the melodies the team worked on four basic elements: timbre, height, intensity, and tone. These elements help to evoke common emotions that may be related to certain colours.

Each colour can be combined with a melody according to the user's choice. Each melody is characterized by five different tones that coincide with the brightness or darkness of the detected colour; this follows the universal concept that shows that light colours correspond to acute sounds whereas dark colours correspond to lower tones.

5.2 Tests for Children with Psycho-Motorial Deficiency

The objective proposed when running these tests was to see if the children were capable of recognizing, naming and memorizing the colour/sounds.

The results showed that the children could in general recognize the colours and name them. They were also capable of combining certain colours to concepts like animals or objects. When asked to memorize the sounds they generally had no problem in remembering which sound corresponded to which concept and they also learned how to associate dark colours with lower sounds and vice versa. The melodies chosen in this case were based recognizable elements of nature (ex. animals) or objects (bells).

5.3 Tests Run through the Internet and on 25 sighted children between 9-13 years of age (First battery)

The COL.diesis group created a game making use of the internet as a means of communication and possibility to reach a large amount of people. In fact about 800 people participated allowing us to collect important and useful information.

The results of the tests showed the team the direction to take with the melodies that had been created, what to correct and what type of melody worked better, responding to the need of colour/melody association, difficulty in recognizing and in memorizing the melody.

A test was also run to define the capability of the users in recognizing the difference in tone achieving very positive results.

The user was asked to listen to a melody that according to the COL.diesis team could correspond to a colour and asked to choose between the six main colours of the colour learning system. The idea was that to see whether the user chose the same colour as the team or if it was preferable to further vary the melody.

The melodies that gave a low result were subsequently varied and adapted to the colour that the team wanted to inspire. According to the results the melody would be changed completely or partially. If the melody showed good results the team decided to maintain it as it was.

For what regards the change in tone, the participants were asked to recognise the variations when presented with the same melody repeated in graver or more acute versions. The results were highly satisfactory as the users had no difficulty in recognizing the change in tone in 73% of the cases.

	Internet, 700 people	25 Children 9-13 years of age	Visually Impaired	Result
Flute	Green/Yellow	Green/Yellow	Green/Blue	Green/Yellow
Banjo	Orange	Not tested	Orange	Orange
Cello	Purple/Blue	Purple/Red	Green/Purple/Red	Purple
Clarinet	Blue	Not tested	Blue/Green/Red	Blue
Guitar	Red	Orange/Purple	Red/Orange	Red
Organ	Purple	Purple	Red/Green	Purple
Marimba	Orange	Green	Yellow/Orange	Orange
Electric Guitar	Red	Not tested	Red/Purple	Red
Trumpet	Red/Blue	Not tested	Purple/Blue	Blue

Piano	Blue	Red/Purple	Blue/Yellow	Blue
Vibraphone	Yellow	Not tested	Yellow	Yellow

Graphic 1: First tests

5.4 Second test with 36 children between 9-13 years of age (Second battery)

Once the results of the first test were studied and compared with the results received from the internet test the melodies that needed to be modified were changed to better suit the characteristics of the colour the COL.diesis team wanted to express.

The variations proved to be very well chosen as the results of the second test show. The amount of children choosing the same colour grew.

	Supposed Colour	36 Children 9-13 years of age	Result
Bata drums	Red	Red	Red
Dulcimer	Yellow	Yellow	Yellow
Piano	Green	Yellow/Blue	NO
Organ	Purple	Purple	Purple
Vibraphone	Yellow	Yellow	Yellow
Classic Gui	Red	Red	Red
Clarinet	Blue	Green/Blue	Blue
Flute	Green	Yellow	NO
Banjo	Orange	Green/Yellow	NO
Viola	Purple	Purple/Red	Purple
Trumpet	Red	Orange	Orange
Marimba	Orange	Yellow	Yellow
Ocarina	Blue	Blue/Purple	Blue
Electri. Gui	Red	Red	Red

Graphic 2: Second tests

6. Results: Project Choices

Thanks to the data that was collected during the research we were able to deduce and decide and choose colour/sound for the device, COL.diesis.

The results and studies helped to create a battery of melodies that in a high percentage represent the same colour to the tested people. The fact that most of the people chose the same colour for the same melody allows the team to see that there is a similitude between the perception of colour and it's representation in music. Colour interpretation is not universal although it does have certain common bases that can be used as a starting point, and because there was a percentage of people that chose other colours diverse from the majority, the team decided to not ignore this smaller but important user group. The device gives the user the possibility to choose their personal interpretation of colour/sound, even if it doesn't follow the majority's choice.

The device is presented with six main colours in order of learning: red, yellow, blue, green, orange and purple.

Each colour can be represented by one of the possible melodies proposed by COL.diesis. As we will be working with the HSV system, the colour will be based on a 360° subdivision. In order to structure the many tones that will be taken into consideration, they will be fragmented into 5 sub-groups from the lightest to the darkest tone of their specific colour.

A melody belonging to a specific musical instrument paired with each particular colour will be associated with each sub-group. There will be 2 levels of difficulty implemented in COL.diesis, represented by the aforementioned groups of 3 or 5 colour/melodies.

The number of tone groups has been set as low as 3 or 5 in order not to cause much confusion when trying to recognize colours and not to use a level of difficulty out of reach of the user; the number of memorable elements should be realistic and not create excessive problems.

Black and white are also taken into consideration. These two represent the distinction between dark and light and are characterized for the white by a Tibetan singing bowl whereas the black is represented by silence: lack of colour, lack of sound.

7. Discussion

COL.diesis is a colour detector designed to help children with disabilities to develop necessary day to day capabilities through game, music and music therapy.

Taking synesthesia as a starting point the COL.diesis team worked around the concept of colour psychology and of correspondent musical interpretation therefore creating a battery of melodies for the project. These melodies have also been designed so that they can be easily recognized and memorized by the user.

The melodies have been programmed into a bracelet that is characterized by its portability and lightness allowing the user to move freely. It can be programmed and adjusted to the needs of the user both in physical size as in the programming of the characteristics (different melodies according to need).

General Objectives

A device has been developed, capable of transforming colour into sound by recognizing and identifying colours and playing them back through musical notes. This new approach will allow the pedagogists to have an additional tool to help them understand the problems and emotions of the blind and people with other types of disabilities. The main contribution COL.diesis gives is the exploration of the infinite range of colours.

The COL.diesis team proposes the use of the device for children between five and twelve years of age applying it in the field of music therapy. It is important to note that this device can be adapted to any didactic-play situation.

The main objective of this device is to give blind children or people with other disabilities a more effective development in their sense of independence, orientation, capability of movement let alone a way to express themselves, socialize, contributing in this form to a social and didactic progress through scientific and technological research.

Specific Objectives, Practical Applications

Psycho-Pedagogical Objectives and Didactic Objectives for the Blind

- Development of the sense of hearing

Music stimulates and increases auditory sensitivity in general and the difference between a blind person that has studied music and one that has not is noticeable. First of all a person who has studied music has a greater capacity of observation, sense of orientation and independence, because they have a deeper knowledge and a stronger training in the recognition of sound in a meticulous way.

COL.diesis is a device which promotes exactly this: the child learns, through games, to recognize not only different musical notes but different musical instruments, sharpening sound recognition.

- Sense of touch – Exploring Objects, Figurative Exploration

Touch represents a tool of effective and essential exploration for the blind. From the moment they are born it is fundamental to stimulate blind children to discover tactile exploration. Curiosity increases if in addition to the sense of touch, the explored object produces sounds. COL.diesis allows any object to produce various sounds according to its different coloured parts. This stimulates and animates the child to explore the object even more so.

- Curiosity

One of COL.diesis' objectives is to stimulate blind children's curiosity and thirst towards knowledge. An object that produces sound thanks to its colour not only pushes the child to extend their hands in search of the object/sound, but it also challenges them to discover the reality and situations that surround them.

- Desire of Independence

Blindness forces the affected person to organize their reality using other means of perception equally capable of elaborating information besides their eyes. The development of personal organization of reality is essential for the blind person's sense of independence.

- Memory development

In this case COL.diesis gives a blind person an infinite amount of combinations between sound and colour that can help exercise their memory. Music and the study of musical notes, has the capacity to capture and to maintain a child's attention and this is valid especially when talking about blind children who use hearing as the strongest tool in order to calm their thirst for knowledge.

- Promote socialization

To be able to socialize and to relate with other people makes one feel confident and boosts their self-esteem. This is a characteristic that children learn through games: they learn to accept the concept of 'you' and 'me' while

playing with others, taking part in roles. In many of the proposed games we can recognize in COL.diesis a possibility to help promote games where more than one child can play.

- Getting to know the body structure

A child learns to recognize their body parts and how they are connected to one another thanks to a long process of personal exploration.

A blind child can easily grow up without a true knowledge of their body structure. As a consequence this can imply a difficult and insecure relationship with their body and its surroundings. Movement cannot be fluid if a child only recognizes their body structure in a superficial manner. This phase of learning is of vital importance.

- Body movement

Independence in movement implies the possibility to explore your surroundings and to feel that the reality that surrounds you becomes yours. Many fears can develop caused by the problem of having to move without being able to see what surrounds your body. These fears are too often passed on to children out of protection towards them. In reality a blind person can develop basic movement capabilities at a very high level.

Through COL.diesis the child can be encouraged to search for objects, learning to bump into things and not to fear movement.

- Sense of orientation

A blind child needs to learn how to orientate themselves in their surroundings. This aspect of knowledge begins with their body and continues with concepts such as right/left, forward/backward, high/low, etc.

Psycho-Pedagogical Objectives and Didactic Objectives for People Affected by Other Types of Disabilities

Although the purpose of COL.diesis was firstly defined for the blind, during its research the idea that it could be developed to adapt to numerous other cases of disability and psychological problems emerged.

- Emotional problems

COL.diesis can be useful to people with emotional problems. Associating colours to emotions through music, they can learn how to exteriorize interior problems that they would find difficulty in communicating otherwise.

These people are often in a general state of unhappiness that could be worked on with activities made possible by COL.diesis.

The device can also promote interpersonal relationships if used with more than one person with games designed to stimulate communication.

- Speech and vocal impediments

People with speech and vocal impediments can find difficulty in controlling the sound of their voice. COL.diesis can help by creating a colour/sound sequence that the user will have to repeat vocally. In this way the user will begin to reinforce their control over their voice. Secondly, the user can begin to recognize sounds (with the help of colour) and to learn musical notes; they will gradually introduce monosyllabic words such as DO, RE, MI, etc. Slowly more notes will be added and the rhythm

will increase. In certain cases, with enough notes, maybe a song could be created with the help of a music therapist.

- Attention-Deficit/Hyperactivity Disorder

A person who is affected by AD/HD has great difficulty in organizing jobs or games. They lose interest immediately and often lose or misplace things.

People with these kinds of problems need to live in a very positive environment where they can find approval at doing something properly, reinforcing their abilities and potential. Certain clear rules must be established with a program of compensation for positive conduct.

Rules and clear routines help on a school level. It is also very important to motivate the child to play very active games where they can move and use up energy.

Any kind of game that implies short periods of concentration can help but COL.diesis can also be used by following a chart where the child's chores are represented. Each chore or positive conduct corresponds to a colour that the child will add to the chart. Once the chart is completed the child can play and listen to a complete tune.

- Learning problems

Learning problems indicate a disorder in one or more basic physiological processes that have to do with the comprehension and use of language, oral and written, or that can be noticed in the difficulty to listen, think, speak, read, write, spell or calculate. It can also include problems such as cerebral damage, minimum functional problems in the brain, dyslexia and development aphasia.

- Mentally Challenged

COL.diesis can give these children the possibility to learn and follow game rules, games concerning movement, speech, etc. Games can be based on logical successions initially characterised by simplicity which in time become more and more complex.

- Down syndrome

These children love games and enjoy sharing experiences. Music attracts their attention and they can learn musical notes and combination concepts like colour/sound. There are many possibilities for games and exercises to be invented, developing capabilities of movement, corporal recognition, memorization, etc.

8. Conclusions

COL.diesis is an innovative system thanks to its original approach to correspondence between music and colour adapted to people with disability using a multi-disciplinary approach.

The choices of correspondence between colour and music have proven to work in a high percentage of people although the subjectivity of colour interpretation has pushed the researchers to maintain an open fan of possibilities for the users.

COL.diesis includes all the important ingredients in a proposal on a social and technological level with the objective to improve accessibility to information and

knowledge. It fundamentally counts on potential user-groups on a national and European level. In addition COL.diesis can be extended to a wider range of problematic situations and disabilities.

The team has developed a portable device capable of detecting colours through a colour sensor and reproducing them through music. The device can be programmed as to adapt itself to the needs of each user.

The team is now entering a phase of product diffusion in the hope to produce the COL.diesis bracelet as to allow potential users to become acquainted with its possibilities and advantages.

The future objective is to formalise the theory through mathematical-colour morphology and sound spaces in order to develop a more objective and formal correspondence between these spaces.

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