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Inclusive science communication: Tools from the natural sounds

La comunicazione inclusiva della scienza: strumenti ispirati dai suoni della natura

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ABSTRACT Scientific popularization for people with sensory disabilities is today insufficient and lacking in specific methods as it uses contents rich in visual and abstract references, difficult to assimilate by those with perceptual or sensory deficiencies. This research aims to fill the gap through an exploratory case study, conducted with an inclusive and multisensory method. This method is based on the use of natural sounds to communicate complex concepts related to ecology and environmental vulnerability. It has a bottom-up approach, starting from a single theme to arrive at the definition of ecosystems and environmental emergencies. The results indicate that natural sounds contribute to students' learning by improving the ability to recognize and describe ecological and environmental issues. The proposed method was highly appreciated by the participants and exhibits excellent performance and great expandability to complex themes.

KEYWORDS Scientific Communication; Sensory Disabilities; Visually Impaired; Inclusiveness; Multi-Approach Method.

SOMMARIO La comunicazione scientifica, strumento efficace di conoscenza e sensibilità ambientale, è piuttosto inefficace per i disabili sensoriali che non hanno esperienza diretta della Natura. Essa, infatti, normalmente utilizza contenuti ricchi di riferimenti visivi e astratti, difficili da comprendere per chi ha carenze percettive o sensoriali. Nel caso studio qui presentiamo abbiamo sperimentato un metodo inclusivo e multisensoriale volto a promuovere la comprensione e l'assimilazione di informazioni ecologiche complesse legate all'ecologia e alla vulnerabilità dell'ambiente. Il metodo è di tipo game-based e utilizza suoni naturali con un approccio bottom-up, in cui partendo da un unico tema si arriva alla definizione di ecosistema e alle emergenze ambientali. I risultati ottenuti confermano che le persone ipovedenti e con disabilità sensoriali sono state perfettamente in grado di svolgere compiti di memoria passiva e si è rivelato efficace, avendo consentito di superare i limiti e la diffidenza basata sulla mancanza di esperienza diretta.

PAROLE CHIAVE Comunicazione Scientifica; Disabilità Sensoriali; Cecità; Inclusività; Metodo Multi-Approccio.

1. Introduction

Globally, 1.1 billion people have vision problems, including 43 million blind (of whom 55% are female) and 295 million visually impaired. For the coming decades, the forecasts are not favorable: both the number of blind and visually impaired is expected to increase (Bourne et al., 2021).

In previous research, blind people were asked what scientific research might do for them. Among the different answers, the need for specific training methodologies was highlighted (Duckett & Pratt, 2001). Unfortunately, scientific dissemination still generally relies on visual imagery and abstract references, which is only rarely adapted to the blind (Jones et al., 2006; Beck-Winchatz & Riccobono 2008).

To be effective, scientific dissemination must be as clear and inclusive as possible, clearly explaining complex and often inaccessible concepts such as those that are not tangible (Bickford et al., 2012). Synthetic information and the use of technology are the main factors that characterize modern scientific dissemination. These tools have benefitted a great development in recent years, becoming an important means for individual and collective enrichment. However, the development of scientific communication tools is still neglecting the needs of blind people and even today tools rich in visual and abstract references are re-proposed, which are difficult to be assimilated by those who have perceptual or sensory deficits (Fraser & Maguvhe, 2008; Papadopoulos et al., 2018; Suimuek et al., 2010). Especially in the study of biology, blind students are excluded from participating in experiments or field activities (Anđić et al., 2019).

In this paper, a proposal is made as to how to adapt complex environmental issues (such as loss of biodiversity, pollution, and changes in agricultural practices) to the needs of the blind people, based on their sensory perceptions. Social practices, such as emotional experience, have been applied in the form of game, that increases well-being and positive psychology, as it has been highlighted by positive testing in science teaching (Businaro, Pons, & Albanese, 2015). To do this, we used tools based on natural sounds, the theme of bird song and in particular the vocal mimicry of bird song species. The method we propose stems from Community-Based Participatory Research (CBPR) methodology (Baron et al., 2009; Wallerstein & Duran, 2010) which involves specialists in different disciplines and target groups.

2. Theoretical background

Efforts to make science dissemination tools inclusive are still sparse (Papadopoulos, Barouti, & Koustriava, 2018; Setti, Cuturi, Cocchi, & Gori, 2018). Most research has suggested designing web pages and web accessibility, but very few experimental studies have been conducted (Suimuek, Altun, & Ateu, 2010). Methods for spreading the key scientific concepts are very much related to visual elements, without any stimulation of the other bodily senses, resulting in poor or absent content inclusion (Ahmetovic et al., 2010), so that disabled people manage to have a very low level of scientific background (Fraser & Maguvhe, 2008). Consequently, people with sensory disabilities (especially those with visual impairment) face problems in the perception of scientific information.

This could be overcome by developing new strategies (Flórez-Aristizábal et al., 2018) to implement science dissemination, drawing inspiration from disciplines such as art, music, or dance (Lesen, Rogan, & Blum, 2016), as well as artistic forms with high communicative value that use all bodily senses in a compensatory way. However, very few examples in this direction are found in literature. Recently, Anđić and colleagues. (2022) show that touch experience using 3D modelling and printing help blind students to distinguish plant and animal cell parts, visualize the cell and its parts, as well increasing student spatial abilities.

Besides touch, listening can also be an innovative means of scientific dissemination. Listening to natural sounds is an important instrument for scientific inquiry. When ornithologists carry out censuses, they use much more hearing than sight to recognize different species, especially in particular environments.

Each environment is characterized not only by different physical and vegetation conformation, but also by a specific, sound landscape that overlaps and increases its total complexity. The soundscape is therefore an element that helps to identify a place and increases or decreases its quality. For example, we know that very noisy places produce changes in the behavior of many animals, including humans, and thus are often avoided by them, in favor of places with a more comfortable sound frequency. When the landscape sound represents just an immersive place, in which animals live and to which they undergo, the soundscape holds a passive function. But it also holds an active function in which the landscape sound is considered an important means of communication (Pijanowski et al., 2011). Birds use sound manifestations extensively as a means of communication, even having a specific organ, the syringes, and a modified larynx, which allows them to emit a great variety of songs, calls, and vocalizations, in respect to other animals.

Singing is of great importance for birds as it is the instrument for contact, courtship, and defence. The timbre is often the peculiar feature of species, thus representing a species-specific identification element.

To the best of our knowledge, there is no research that explores the contribution of natural sounds to science dissemination, which was the reason for choosing an exploratory case study for our research.

3. Context

The research was proposed as part of an "inclusive communication" experimentation path developed by the National Research Council of Italy (CNR) in collaboration with the "Florio Salamone" Institute of the Blind of Palermo. The CNR researchers were specialized in Ecology and Biodiversity and had a great knowledge of science dissemination, developed over the years with many projects targeted to schools of all levels. Specialists from the Institute of the Blind were involved in the design of the laboratories, including the director, sociologists, psychologists, and social workers. The users of the laboratory were subjects who usually attend the institute for recreational and educational activities and who have already developed a relationship of trust with the staff.

The group of specialists devised a playful educational path aimed at increasing knowledge of the natural environment and the related management aspects; these themes had never been proposed in the previous activities of the Institute. After getting to know and become familiar with the blind or visually impaired students of the Institute, their degree of knowledge of natural systems and their appreciation and interest in natural themes was verified through discussions and debates. Following these exchanges of views, it was decided to further explore the theme of birds and their protection as the aerial environment and the world of birds seemed to be the least known. Most of the blind and visually impaired had also shown distrust and circumspection towards these animals; also a blind woman said she was afraid of birds, calling them dangerous and unreliable. To increase knowledge and try to increase familiarization, a cognitive path was then formulated.

Participants consisted of three groups of users with different sensory characteristics (Table 1). The first group consisted of 23 visually impaired people, the second group of 20 blind but blindfolded people, the third group consisted of 20 sensory disabled people, with mild to moderate mental disorders, cognitive impairment and some with developmental delays. 50% of this sample was totally blind, 25% visually impaired, the remaining 25% normal sighted. The whole cognitive path was formulated in a series of meetings in which the biology and ecology of birds were discussed through meetings, games and manipulative activities, such as building nests, manipulating eggs and feathers, building-colored wings, the combination between the shape of the beak and food, etc., activities that allow an increase in confidence with the theme. The last of these activities was the game on bird songs and their recognition, which will be explained in detail below.

We informed users that their responses would be recorded as scientific data. During the activities, we followed the ethical principles of the Declaration of Helsinki and collected information about the participants after obtaining their written consent or that of their parents/legal guardians.

Table 1. Composition of the groups of participants in the laboratory.

Characteristic of the Group	Females	Males	Age	Vision skills
Group 1: Blind or visually impaired	12	11	19-64	50% Blind 50% Low Vision
Group 2: Normally sighted	10	10	18-20	Normally sighted but blindfolded
Group 3: Down and Williams-Beuren Syndromes	2	18	18-30	50% Blind 25% Low Vision 25% Blind

4. Methods

To understand how natural sounds influence and contribute to knowledge and learning processes in inclusive classrooms, we conducted an exploratory case study. Cohen, Manion and Morrison (2000) and Yin (2018) recommend that an exploratory case study should be used when there is not sufficient prior research. Mills, Durepos and Wiebe (2009) also suggest that the exploratory case study should specify procedures for the collection and processing of data, so that they can be used for future research. Therefore, in the following we describe in detail all the steps in our case study.

4.1. Structure of the proposed activities

We proposed a playful-practical laboratory, envisaging a kinaesthetic part to allow a sensory disabled public, with varying degrees of blindness, to reach zoological and scientific contents and therefore reconnect to more general problems, such as the numerous environmental emergencies for this decade.

The activities started with two familiarization meetings where the group of specialists and that of the users introduced themselves, had a snack together and discussed environmental issues, exchanging information and curiosities to understand how much interest there was on these topics and whether such an experimental activity with birds could be interesting for them. After assessing the topic positively, we entered the heart of the activities.

The third meeting focused on birds and their biology to introduce the main concepts on the ecology of these species. A lecture was given, lasting half an hour; then, users were proposed to observe and manipulate small fake birds, made with real duvets / bird feathers. This activity was aimed to decrease fears that these animals aroused in some subjects. Subsequently, we proposed the use of bird songs, and all together decided the methods of development, identifying the objectives. All users chose to participate in the laboratory and chose their partner in the couple's activity.

4.2. Contents and objectives

Targeting an audience affected by various degrees of visual impairment (see Table 1), we needed a bird model species that would simultaneously represent a stimulating attraction at a multi-sensorial level, and that would allow us to convey environmental concepts. So, we chose the Calandra lark Melanocorypha calandra, a medium-size Passeriformes, from the family of Alaudidae and with a mainly Mediterranean-Turanic distribution (Mediterranean countries, Central Asia). Mainly steppe-like songbird, it has a strong and very varied song. Males sing in flight or from raised perches throughout the entire breeding season. The peculiarity of this species is the mimicry song: they include several insertions, within its own song, of short phrases or verses of other drylands bird songs, thus enriching their own vocal repertoire (Dalziell et al., 2014). In his courtship, the better he does it, the higher the probability of being chosen by a female.

Taking advantage of this imitative behaviour, we wanted to understand if users with sensory disabilities a different tendency had to recognize imitations, compared to able-bodied subjects and if this listening-based methodology was able to convey complex information and help memorize them.

More in general, we wanted to verify whether – thanks to the proposed set of activities - it was possible for our users to store a large amount of completely unknown information and stimulate curiosity and memorization of these concepts.

This laboratory also allowed us to verify whether the methodology was suitable for blind people and people with syndromes, in comparison to people with normal skills.

4.3. Materials and technologies

The tactile part of the laboratory consisted of the manipulation of 6 statuettes of the species whose songs were those of the species imitated in the audio part. The 6 species selected were: Little owl (*Athene noctua*), Eurasian goldfinch (*Carduelis carduelis*), Linnet (*Carduelis cannabina*), House sparrow (*Passer domesticus*), Crested lark (*Galerida cristata*) and Yellow Motacilla (*Motacilla flava*) (Table 2). The remodels/copies of the species were faithful done in terms of colour and size, they were made using brown DAS and then painted with tempera colors. The natural colors of the species were emphasized to facilitate visualization for visually impaired people, breaking down their perceptual barriers.

The audio-video part of the laboratory consisted of the audio track of the 6 species mentioned, and two videos that reproduce their own songs and the imitative songs of the Calandra Lark males. The audiovisual part of the experiment was conducted with a simple laptop and two pairs of noise isolating headphones. The songs were selected after having seen dozens of them with the male singers of Calandra uploaded to free web platforms (YouTube, Vimeo, Veoh). The selection criteria were the following: imitations of at least 3 of the 6 selected species, good acoustics, subject in the foreground. The audio track was extracted from the selected tracks using the free downloadable program Audacity[1], to scientifically attest the imitation of the bird's call picked up by the human ear; the traces were visualized on the spectrograms (Figure 1).

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[1] https://www.audacityteam.org

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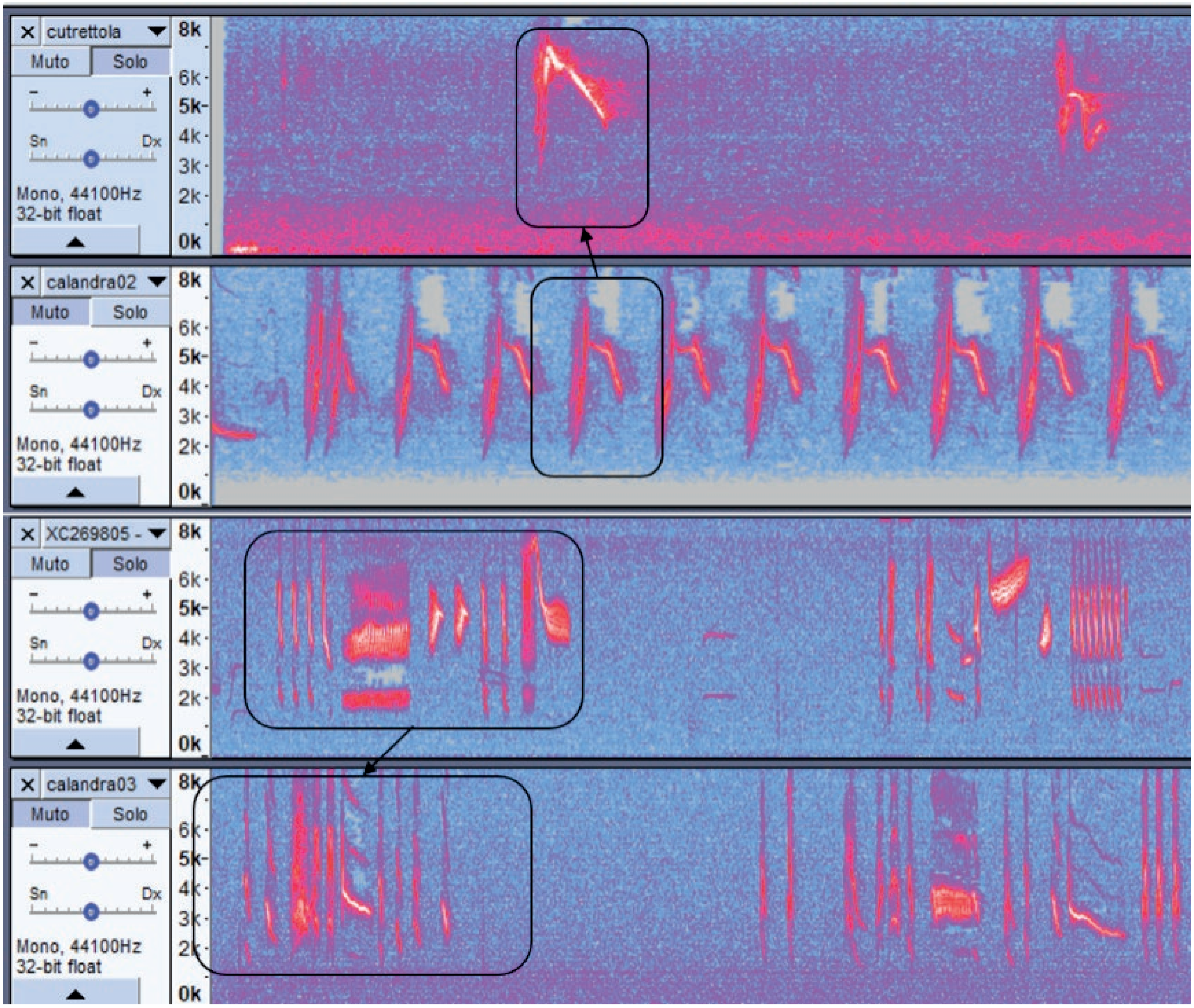

Figure 1. Spectrograms of vocal mimicry of Calandra lark bird (2nd and 4th stripes) compared to imitated species: Yellow wagtail (1st stripe) and Linnet (3rd).

4.4. Data collection

The audio testing was carried out in two different phases. The subjects, in pairs, were seated on two comfortable chairs and the audio device was positioned at 50 cm, with an imaginary line between the two users. Each user was equipped with insulating headphones to listen to the audio tracks without external distractions. In the first phase, the audio track of all the imitated bird species was heard twice, accompanied by an image of each species, a brief oral description and some characteristics of their singing. In the meanwhile, the user was free to look at and explore with both hands the scale statuette of the imitated species, to become familiar with the species. Then, we played a "audio test" reproducing the proper sing of a male of Calandra Lark, to allow the user to get used to his singing when he is not making imitations. The spectral density of the Calandra Lark's song was compared with the spectral density of other birds' songs, to access the actual mimicry of the bird song in the audio track.

Finally, we reproduced the imitator bird tracks, in which it alternates its song with that of other birds. Both songs lasted about a minute and after that they were able to respond to what they had heard. At the end of the session, we asked users how many bird species they recognized by pointing to the name, or by touching the species they recognized with a pointer.

In the six months following the activities, we organized a visit to CNR with the blind participants. During the visit we were able to ascertain that the group kept the memory of the birds, their ecological importance and the division into species of the bird object of the game. After several months, the group asked us again to organize new sessions and speaking with the psychologist of the Institute, he showed that he remembered the contents of our workshops which he considered fun and interesting experiences. For us, this is certainly an indication of appreciation of this type of experience and strengthens our belief in its usefulness.

5. Results

User responses were recorded and subsequently statistically weighted in a score system. From the users' answers, the number of species imitated in the video is taken on the total number of species indicated by them. A statistical correction is then applied: given a certain number of detections, it represents the probability (between 0 and 1) that user must guess the 4 species by pure chance. It is therefore maximum when the user mentions all 6 potentially imitating species, 0 if the user indicates less than 4 species. The use of this index is aimed at considering that the user indicating a high number of imitated species is more likely to score higher by pure chance. In fact, if all 6 species are named, undoubtedly the 4 presents in the video are guessed. Users who cited many species receive a greater penalty than those who cited a few. The final score is calculated as the number of correct answers, subtracting the penalty and statistic correction. In order not to report negative values, the final ranking is normalized to 0. Graphics and statistical analysis were performed with R, spectrogram is performed with Audacity.exe.

All three groups scored on average above 0 (Figure 2), with a median value of 3 for sensory disabled and 5 for normally sighted and blindfolded. We noted differences between all three groups, if we consider the values of statistical averages: 3.10 ± 1.79 for sensorial disabled (max score 6, min score 0), 4.42 ± 1.66 (max score 6.67, min score 1) for normally sighted and 4.97 ± 1.22 for blindfolded (max score 6.67, min score 3). The percentage of wrong answers was 41% for sensory disabled, 30% for normally sighted and 25% for blindfolded.

In general, considering the totality of the right and wrong answers given during the sessions, it was noticed that normally sighted people tend to choose the more colored and flashy species, while this preference is not evident in the groups of sensory disabled and blindfolded (see Table 2). Furthermore, sensory disabled people tend to use species with names known and used in every-day language, rather than the species whose names are not common (see Table 2). This did not occur for the other two groups. However, this tendency has no statistical significance (T test gives all result with $p > 0.05$), probably due to the small size of the sample. The implementation of correlation analysis has not shown statistically significant correlation between the users ages and the experiment performances.

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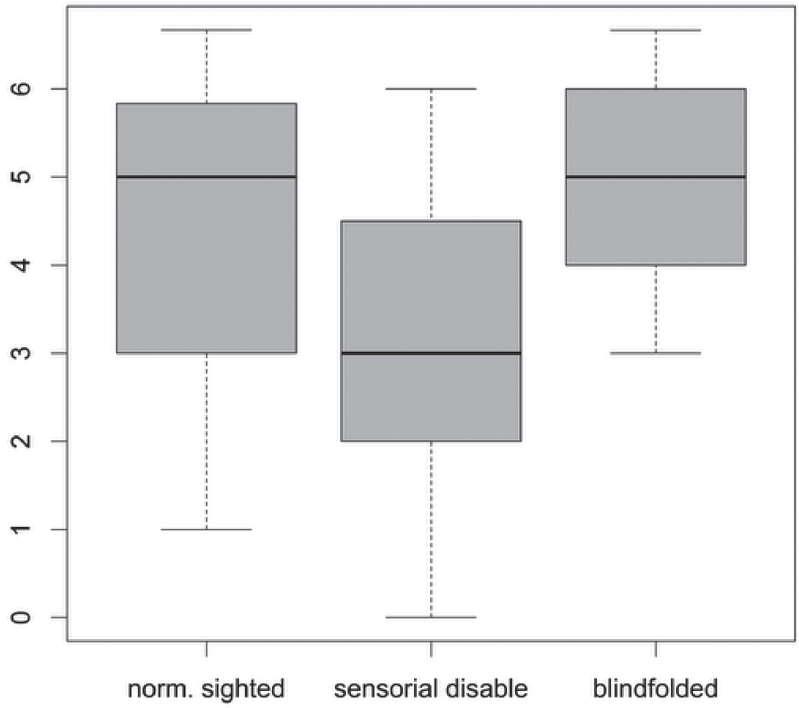

Figure 2. Boxplots of test results. In y axes the test score.

Table 2. Variables of birdsong taken into consideration: appearance of the plumage and use of the specific name even among those not in the ornithological field.

Species	Colours		Name	
	Bright	Fawn	Usual	Unusual
Crested Lark		X		X
EurasianGoldfinch	X		X	
House sparrow		X	X	
Linnet	X			X
Little owl		X	X	
Yellow wagtail	X			X

6. Discussion

In the present study, our first aim was to test a method to make available contents that would have been otherwise difficult to access for sensorial disabled people. We wanted to test whether a multisensory approach could improve performance in the assimilation of scientific contents and whether this effect would be of help for blind people.

In fact, our method was based on:

1) a tactile approach given by the physic representations of the imitated species,
2) an acoustic approach to memorize/recall the different songs by an imitating species and identify them as distinct sequence in the audio file, and

3) a visual approach (for normally sighted and visually impaired people) by brightening colors in representations of imitated species.

Positive results obtained by all groups confirm that, despite the lack of vision, sensorial disabled people can perform passive memory tasks, as long as they are asked to remember sequences of unspatialized sounds, associated to the active manipulation of objects.

A reason for the lower performance of sensory disabled people could lay in the fact that blind and visually impaired subjects are often reluctant to face new situations, especially those they are not able to fully control. This was especially evident in our case for some users who present some aspects of the autistic spectrum. We noticed that the active manipulation, the explanatory meetings and our continuous descriptions, even during the test, seemed to have mitigated the initial attitude of diffidence shown by the disabled people towards the birds (see introduction), which instead seemed amused and more confident. With the introduction of identity and meaning for the birdsongs, related to a physical animal, sighted individuals were able to construct, and subsequently use, a functional image of the scene that helped them to locate and remember the sounds. The lack of vision leads to specific difficulties when congenitally blind individuals must create interactive images that involve several items at the same time. Simultaneous perception and manipulation of more than one object is typical of vision, while haptic and auditory perception, widely used by visually impaired individuals, mostly rely on sequential processing. Vision facilitates simultaneous processing at high cognitive level and thus the absence of vision might reduce the ability of visually impaired people to properly process large amounts of information at the same time (Rios-Chelen et al., 2012).

Having therefore the foresight to divide the stimuli in such a way as to focus on one species at a time, so as to assimilate the song well, the shape of the bird's bodies and the characteristics of each individual species, allowed the sensory disabled to be able to recognize an identifying element (the song of the species) within a heterogeneous pattern faced for the first time as a stimulus (the song of the Calandra lark and its imitations). Preliminarily, we found during the test that the sensory disabled had positively independently recognized some of the songs of the six species examined, especially those related also to urban contexts (Linnet, Eurasian Goldfinch, House sparrow) and previously heard, but not associated with any species, for lack of prior knowledge. The group of disabled people also showed strong positive feedback in the science dissemination lessons that preceded and followed the experiment: the majority of those who positively recalled the experience and could argue the biology and the ethological peculiarities of the Calandra Lark Bird, remembering also which species they had heard singing. This method allowed them to learn complex scientific issues quickly, using a bottom-up approach that from single elements (the birds of agroecosystems) rose towards the ornithic communities, the definition of ecosystem and the environmental emergencies of agroecosystems. Our experiment allowed us to study how the exploration of an inclusive method, using a multi-sense approach, impacts on storing and recalling of scientific information. Although both sighted and blind individuals show similar audio memory skills, the latter have only a partial access to abstract scientific concepts processing of multiple stimuli, even if presented through a non-visual modality (Setti et al., 2018). This result is also important in the context of developing new solutions and technologies to enhance environmental representations in visually impaired individuals. It is interesting to note how the blindfolded group, despite similar results to the normally sighted (even higher, considering the statistical average) acts similarly to the group of blind and visually impaired people. Given the impossibility of storing species by visual memory, this group did not show a selective preference for the most colorful and showy species, which instead had a greater appeal to sighted people. We also think that the high performances of this group, bigger than the other two, are due to the impossibility of seeing the video, where the moving image of the singing Calandra Lark Bird can provide a possible distraction, influencing the concentration during the test and the detection of the imitated songs.

7. Conclusions

We have provided vocal, visual, and auditory codifications to facilitate the mental representation of a concept, starting from a single stimulus (the song) to then move on to a series of stimuli in series (the imitative song of the Calandra Lark Bird) and introducing an intangible argument through environmental interpretation (biodiversity loss, pollution, and changes in agricultural practices) through other sensory modalities. This scientific result suggests that the storage of spatial contents works by storing information in a pictorial and descriptive manner (Dalziell et al., 2014) and such are the stimuli we provided to increase the inclusiveness of our scientific contents: representations through objects with vocal and acoustic descriptions of concepts to memorize. Creating inclusive methods means offering everyone the opportunity to reflect on issues of social and environmental interest, which have important repercussions on daily life and the future of humanity. With this vision, we believe inclusive science dissemination activities should evolve rapidly becoming more effective, creative, and inclusive. Although the perception of this phenomenon seems to be growing, science communication must have a common goal: to involve everyone and provide adequate tools for inclusive communication. In this work we wanted to experiment with a small useful tool to bring those with sensory and perceptive difficulties closer to nature, its species and the issues of environmental sustainability in the hope that tools such as the one we have experienced can be increasingly widespread in scientific dissemination.

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