FONDAZIONE ISTITUTO ITALIANO DI TECNOLOGIA

A TECHNOLOGY TEASER

AUDIO SOCIAL TECHNOLOGY DEVICE: ABBI

Released on April 2016

INTERACTIONS

Istituto Italiano di Tecnologia – Mission and History

The Foundation is intended to promote Italy's technological development and advanced education, consistent with national policies for scientific and technological development, thus strengthening the national production system.
For this purpose, the Foundation:

- helps and accelerates the development, within the national research system, of scientific and technological skills able to facilitate state of the art technological advancements of the national production system;

- develops innovative methods and know-how, in order to facilitate new high-level practices and positive competitive mechanisms in the field of national research;

- promotes and develops scientific and technological excellence, both directly, through its multi-disciplinary research laboratories, and indirectly, through a wide collaboration with national and international laboratories and research teams;

- carries out advanced training programs as a part of wider multi-disciplinary projects and programs;

- fosters a culture based on sharing and valuing results, to be used in order to improve production and for welfare-related purposes, both internally and in relation to the entire national research system;

- creates technological understanding about components, methods, processes and techniques to be used for the implementation and interconnection of innovative products and services, in strategic areas for the competitiveness of the national production system;

- pools research scientists operating in various research institutes and establishes cooperation agreements with high-level, specialized centers;

- promotes interactions between basic research and applied research facilities, encouraging experimental development;

- spreads transparent, merit-based selection mechanisms for research scientists and projects, in compliance with globally approved and established criteria.

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EXECUTIVE SUMMARY

Among human senses, sight has by far the greatest influence on perception of surrounding environment. Lack of visual experience, in addition to the major difficulties in daily living, can slow down or hamper the normal development of the sense of space. It makes difficult, if not impossible, to interact with distant events, persons and objects. For example, blindness has an impact on the ability of children to engage in games at school or at home, to interact with their parents or peers. As a result, children with visual disabilities have often difficulties engaging in positive social interactions, which can impact the development of their personality. In all countries, a large number of associations and institutions are dedicated to help children to overcome their disability and become autonomous and independent persons.

IIT is developing a new set of audio-based devices to improve the social abilities of visually impaired children and adults. At the moment, this research has led to the development of a wearable device, the *Audio Bracelet for Blind Interaction* (ABBI), that can be programmed to produce sounds when the user moves in certain ways and/or particular conditions. The primary function of the ABBI device is not to replace vision by another sense, like most systems for visually-impaired persons, but to fully develop the abilities and skills of visually impaired persons, in particular children, so that they might gain major autonomy even in the absence of the device. For this reason, ABBI is often defined an “habilitation device”.

This technology represents a unique chance for companies active in health and children care sectors and willing to branch out into different market areas. IIT assets appear well positioned for an out-licensing strategy, providing the licensee partner with the ability to take care of the late stage development, CE certification, scale-up and production process. The licensee should guarantee a high probability of market success based on consolidated marketing & distribution organization. A typical licensing strategy based on entry fee and subsequent royalties on net sales can be envisaged.

INTELLECTUAL PROPERTY

PCT International Application #
PCT/IB2015/052749
Priority Application #
TO2014A000323, April 16, 2014
International Publication Date
22 October 2015 - WO 2015/159237
Applicant
Fondazione Istituto Italiano di Tecnologia
Inventors
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Title
Wearable Sensory Substitution System, In Particular For Blind or Visually Impaired People

Short Description:
The system comprises at least one module including: a sensor apparatus for being worn by a user and designed to detect data representing the arrangement assumed within the space by the part of the user's body on which the sensor is worn; a signaling apparatus for providing a signal that can be perceived by the user; a control unit connected to both sensor and signaling apparatus and configured to receive data from the sensor apparatus and to control the signaling apparatus as a function of the data. The control unit is configured to calculate or receive an estimation of kinematic parameters referring to the movement performed by the sensor apparatus worn on the part of the user's body as a function of data. It is also configured to control the emission of the signal, when the estimation of kinematic parameters fulfills criteria that are predetermined or can be determined discretionally.

IIT TECHNOLOGY

ABBI is based on the idea of using the auditory modality to convey spatial information about the movement of the person's main effectors/limbs (such as the wrists and feet). The movement of the visually-impaired person is therefore associated with an auditory feedback that provides spatial information related to the position of the body in the space (an information which is usually conveyed through vision). Research has shown that the association of a sound source with the movement of the person is a natural way to link action and perception, which is fundamental for the development of the sense of space. These sources of sounds allow the visually-impaired child or adult to associate body movements with the position of the limbs in the space and, consequently, to build a representation of his/her body movement in the space in an intuitive and direct manner. In addition, sound sources placed on other persons provide a better sense of the events taking place in the environment and to improve social skills of these children and adults (Figure 1). By tackling the impact that blindness might cause on cognitive processes that contribute to the normal development of the sense of space, it is possible to alleviate problems that might derive from having an impaired sense of space, such as a lack of mobility, poor navigation skills, limited interaction with others.

Figure 1. Visually-impaired child holding an ABBI device in his hand

Technologies supporting involvement of children with visual disabilities address a big societal challenge. Despite a wide range of assistive devices available, user acceptance is quite low. The most popular sensory substitution systems used by the blinds remain the Braille, that dates back to 1829 and is taught to only 10% blind children, and the white cane (http://home.earthlink.net/~blindworld/NEWS/6-06-14-02.htm). Creating new solutions is particularly important for the youngest part of the population to whom the role of technology can be directed, not only to supplement missing or defective functions, but also to support the optimal development of motor and sensory abilities.

ABBI Main Functions

ABBI has the following characteristics:

- ***Audio-motor association.*** The core functionality of the ABBI device is to produce a sound that can be triggered and/or modulated by the motion of the user. For example, ABBI can playback a recorded sound files when a motion is detected, modulate a synthetic sound as a function of the user movement to give sounds to movement, etc.
- ***Communication and control.*** Besides producing sounds, the ABBI device can store in a log the activity of the user, send notifications about the user motion and communicate with any recent smartphone and computer. All these functions can be configured to be tailored to the application and, possibly, to the preferences of the user.
- ***Web access.*** Through the smartphone or the PC, remote access to the ABBI device might be possible from internet to ensure, for example, that the rehabilitation or training protocol is well followed.
- ***Versatility.*** The ABBI circuit can be mounted in various configurations to accommodate the needs of the different applications; it is small and light enough to be used by a one-year old child and might also be mounted within objects (e.g. toys) to make them audible to the visually impaired population.
- ***Simplicity and user friendliness.*** Simplicity was an important goal in the design of the ABBI system. Once it has been configured, the ABBI device can function independently, without any particular intervention from the user. Both the hardware and firmware are designed with the idea that ABBI would "wake up" when the user wears it, and would "fall asleep" when left alone. This simplicity makes it possible to use ABBI from the first year of life.

Hardware

The ABBI device encompasses a custom-designed electronic circuit, a battery and micro-speaker and/or headset connector (see pictures below – Fig.2). The electronic circuit has been designed by the IIT for the ABBI project. This high-density six-layer circuit has a small size (25 by 24 mm) and includes a powerful microcontroller (Arm Cortex M3), an audio amplifier, a low-energy ("Smart") Bluetooth communication module that can communicate with any recent smartphone and computer, an Inertial Motion Unit (IMU) that includes an accelerometer, gyroscope and magnetometer to sense motion, a 16 Mb Flash Memory to store sound files and/or log the activity of the user, a micro-USB connector to charge the battery, update the firmware and upload/download large files.

Figure 2. ABBI device and ABBI battery and micro-speaker

Software

The ABBI system includes several applications, which provide various degrees of control of the device such as ABBI Apps for smartphones and PC applications to control advanced functions of the device. For example, the user might employ a common smartphone application to monitor the battery level of the device or to change the volume of the sound. More advanced applications can be used by the rehabilitator and/or scientist to tune the functions of the ABBI device or retrieve information stored in it.

Key technological aspects

- The ABBI approach is based on state-of-the-art understanding of how spatial cognition develops and the possible long lasting effects of blindness during the most critical years of sensory, motor and cognitive development. The ABBI technology was developed by a team of psychologists, experts in the cognitive and sensory development of visually impaired people and professionals that interact everyday with blind people.
- The ABBI device is simple to use. Many Sensory Substitution Devices (SSD) are difficult to use because they overwhelm the human brain processing capacities. Blind individuals using SSD can be overloaded by the wide amount of acoustical and tactile signals coming from these devices. Experience and many user studies show that the systems must be relatively simple to use in order to be adopted. This is the case, for example, of the audio books, the white cane, the guide dog and the echo-locating using tongue clicks or cane tapping sounds.
- The ABBI uses the natural abilities of the human brain to process the position and movement of the sound sources in the space and, therefore, it does not require the user to learn a new "language" to understand substitutive signals. It exploits information that can be naturally decoded by the hearing system. Positions, motions and activities of the persons or objects associated to these sounds sources are learned implicitly, unconsciously through everyday natural training. In that sense, the ABBI is a simple interface, like the white cane, which is more natural than other more technologically advanced devices.
- The ABBI technology does not require learning complex language to work, so that it can be used by very young children, from the first years of life (as opposed to other sensory substitution devices that are introduced in late childhood or adulthood). Moreover, ABBI can be also easily integrated in the daily life of children at home.

ABBI Applications

This section illustrates several needs and applications currently under development for the ABBI system in collaboration with professionals in various rehabilitation fields:

- ***Spatial cognition training:*** In this application, the ABBI system is used to provide audio feedbacks about the movement of the child by positioning a sound source on his/her wrist or ankle. In this configuration, the ABBI system could be used by young children (one to five-year-old), at an age when such a training is most beneficial.
- ***Balance and mobility training:*** Vision also provides information that is used to maintain balance. The ABBI system can be used to train visually-impaired persons to maintain their balance by providing audio feedbacks about the movement of their body.
- ***Navigation training:*** Visual-impaired people hesitate to move and explore their surroundings. Equipped objects and people in the room will encourage visually-impaired people to explore their surroundings and help them to develop a representation of the space around.

- ***Social interaction training:*** Visual impairments make it difficult, if not impossible, to interact with distant events, people and objects that do not produce any sound. Many joint actions like lifting something together, joint play etc… rely on visual feedbacks. In this application, several people will wear an ABBI, which provides feedbacks about their position in the room and their activity. Special games have been developed to encourage playful activity in small groups of children.
- ***Sport and other applications:*** The characteristics of the ABBI system also makes it possible to envision other applications beyond the particular rehabilitative context. For example, visually impaired people could take advantage of the technology developed within the ABBI project in many sport activities, such as football: the use of a sound positioned within the ball could help the player to better identify the position of the ball in the field and to improve interaction between players during the game.

The ABBI system and its applications are being developed with the active involvement and participation of rehabilitators and therapists, who have extensive experience in working with visually impaired people. In particular, it is worth mentioning, an ongoing, long lasting collaboration with Istituto David Chiossone Onlus in Genoa and the joint lab established in their premises to assess the effectiveness of new devices and rehabilitation.
In this context, the ABBI system is intended to be used as a complement to existing tools and techniques currently used by rehabilitators, both at home and in public contexts.

More information about ABBI initiatives and about how ABBI device works can be found at the following links:

http://bit.ly/2380LKw (video in Italian) or http://bit.ly/1resilg (short video in English)

IIT survey with stakeholders and opinion leaders (Institutions, professionals, etc..) working in this sector suggest that there is a strong unmet medical need for new technologies and service to integrate existing methods used to help visually-impaired people, which has yet to be fulfilled. The validity of the system is supported by experimental studies demonstrating that the association between the sensory and motor systems is vital for the development of visual-like spatial abilities: this is a central characteristic of the ABBI approach.
More details about the market and the demand of this type of devices can be found in next paragraphs.

MARKET ANALYSIS

Currently 285 million people are estimated to be visually impaired worldwide: 39 million are blind and 246 have low vision. About 87% visually impaired people of the world live in low-income settings. Globally, uncorrected refractive errors are the main cause of moderate and severe visual impairment; cataracts remain the leading cause of blindness in middle and low-income countries (data from WHO Fact Sheet N°282 2014).
In Table 1 is reported the number of visually impaired people and corresponding percentage of the global impairment by the WHO region and country in 2010.

Table 1. Population of visually impaired people in the World

		Blindness	Low vision	Visual impairment
WHO Region	**Total Population (millions)**	**No. in millions (percentage)**	**No. in millions (percentage)**	**No. in millions (percentage)**
AFR	804,9 (11,9)	5.888 (15)	20.407 (8,3)	26.295 (9,2)
AMR	915,4 (13,6)	3.211 (8)	23.401 (9,5)	26.612 (9,3)
EMR	580,2 (8,6)	4.918 (12,5)	18.581 (7,6)	23.499 (8,2)
EUR	889,2 (13,2)	2.713 (7)	25.502 (20,4)	28.215 (9,9)
SEAR (India excluded)	579,1 (8,6)	3.974 (10,1)	23.938 (9,7)	27.913 (9,8)
WPR (China excluded)	442,3 (6,6)	2.338 (6)	12.386 (5)	14.724 (5,2)
India	1.181,4 (17,5)	8.075 (29,5)	54.544 (22,2)	62.219 (21,9)
China	1.344,9 (20)	8.248 (20,9)	67.264 (27,3)	75.512 (26,5)
World	**6.737,5 (100)**	**39.365 (100)**	**246.024 (100)**	**285.389 (100)**

Table 2 reports the distribution of blind and low vision individuals in various countries. The incidence and demographics of blindness vary greatly in different part of the world. It is estimated by the World Health Organization (WHO 2010) that 87% of the world's blind people live in developing countries (from WHO/NMH/PBD/12.01).

Table 2. Geographical distribution of visually impaired persons in the world

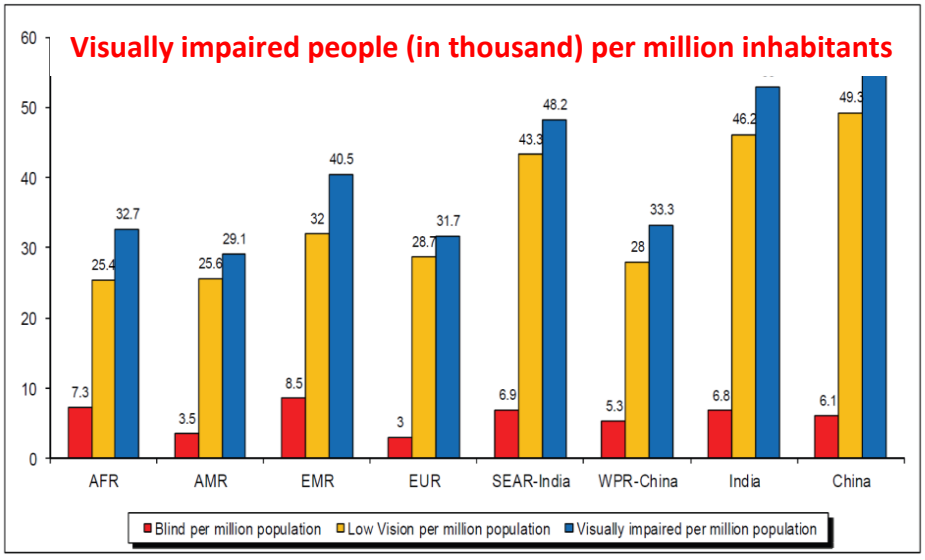


Table 3 reports the global estimate of people with visual impairment by age in 2010; for all ages in parenthesis the corresponding prevalence (%). There is a sustained increase in the number of people who are blind or visual impaired from conditions related to longer life expectancies: this trend is visible especially in richer countries where this group of people has a higher willingness to pay for healthcare services and products. As shown in the following table, the majority of visually impaired people are aged 50 years of older. It is estimated that there is a per-decade increase of up to 2 million persons over 65 years with visual impairments. This group is growing faster than the overall population (data from WHO Fact Sheet N°282 2014).

Table 3. Age distribution of visually impaired persons

Ages (in year)	Population (millions)	Blind (millions)	Low vision (millions)	Visually impaired (millions)
0-14	1.848,50	1.421	17.518	18.939
15-49	3.548,20	5.784	74.463	80.248
50 and older	1.340,80	32.160	154.043	186.203
All ages	**6.737,50**	**39.365**	**246.024**	**285.390**

An estimated 19 million children are visually impaired. Of these, 12 million children are visually impaired due to refractive errors, a condition that could be easily diagnosed and corrected. 1.4 million are irreversibly blind for the rest of their life and need visual rehabilitation interventions for a full psychological and personal development. Besides, it is estimated that by the year 2020, all-blind related numbers will double (data from WHO Fact Sheet N°282 2014).

Both blind and low vision patients might be considered as potential ABBI users (285 million in total worldwide).

Considering that Italy will be ABBI first end-user market, on the right is reported the distribution of blindness in Italy per region (data from ISTAT 2012).

Regions and autonomous provinces	Population (Num.)	Blind people (Num.)
Piemonte	4.457.335	8.885
Valle d'Aosta	128.230	260
Lombardia	9.917.714	13.907
Prov.Aut. Bolzano *	0	0
Prov.Aut. Trento *	0	0
Veneto	4.937.854	8.263
Friuli Venezia Giulia	1.235.808	2.038
Liguria	1.616.788	3.437
Emilia Romagna	4.432.418	7.483
Toscana	3.749.813	3.783
Umbria	906.486	2.351
Marche	1.565.335	3.530
Lazio	5.728.688	11.482
Abruzzo	1.342.366	4.720
Molise	319.780	1.113
Campania	5.834.056	11.098
Puglia	4.091.259	10.404
Basilicata	587.517	1.920
Calabria	2.011.395	5.906
Sicilia	5.051.075	18.028
Sardegna	1.675.411	5.078
Totali	60.626.442	129.127
Popolazione residente: DATI ISTAT 2012		
* in applicazione della L.191 art. 2 commi 106/126		

COMPETITIVE SCENARIO

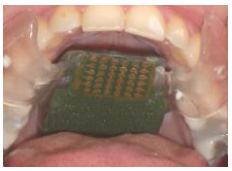
The ABBI system has no real competitors, although a wide variety of products for blind persons are already available (https://www.afb.org/prodmain.asp). Existing products seems to meet, individually, the following different needs:

- **Information Transmission**: any Braille-based device; these devices convey information generally through a tactile experience.

For example, Finger-Braille interfaces with wristwatch computers have been developed and are capable to send information to the blind person. The computers are linked to six fingers (three per hand), which receive vibrations according to Braille language. This system allows to interact through Bluetooth devices.

- **Mobility Assistance**: these devices allow to have spatial information about the environment; there's a great variety in this category: from the cane to technical devices worn on belt, feet or even head which assist visually impaired people with the movements.





The first two pictures represent devices worn on wrist and on head. They gather information about the obstacles and send alerts to the user; the third picture is a device which conveys information to the user by stimulating the tongue (e.g. to provide spatial information coming from a videocamera). The forth picture shows a device which has to be worn on belt and gives information about the obstacles through a tactile display. The last picture shows a vibrating sole that conveys signals to the blind person in the form of vibrations encoding simple information such as directional instructions and familiar patterns.

- **Computer Access**: these devices facilitate the use of technology (e.g. voice synthesizers).

All existing products tend to focus on just one specific need and generally have side effects. Instead, ABBI system, with an approach based on the exploitation of human perceptual abilities, at a certain level meets all the needs listed above. Furthermore, many of these products are low-level technology products, similar to those used by sighted people, except that they have been adapted to be used by blind people. Other products, such as the cane for navigation and Braille displays to read, provide only essential information to the blind persons.

The sensory substitution devices (SSDs) described above aim at conveying visual information through a different modality. However, the wide amount of tactile or acoustic signals coming from these devices tend in general to overload the capacity of blind individuals to process this information. Besides, learning how to interpret those signals generally requires long training time, patience and effort from the user. As a result, SSDs have not been widely adopted by visually-impaired people.

Unlike SSDs, the ABBI device is a (re)habilitation-oriented device. The goal of the ABBI concept is to increase the autonomy of the individual by exploiting normal auditory abilities and not by conveying visual information through a different sensory modality like most SSDs. In that sense, the ABBI device and, more generally, the approach underlying this project is different from most projects oriented toward the development of technology for visually-impaired people. The unique characteristics of the ABBI device include a small size, a sound source in the device, a capacity to modulate the sound as a function of the movement. Specific hardware had to be designed to implement the concept because a review of existing devices suggested that existing technology does not fit the needs of ABBI.

Rivalry to ABBI technology could also come out from further mobile and/or wearable technologies like smartphones, smartwatches and micro-controller platforms. Smartphones are nowadays powerful computer endowed with motion sensor and which could be programmed to produce sound as function of the movement. Even low-cost entry level smartphones could be used for that purpose. However, smartphones are too big to be worn on the wrist and too complex (and perhaps fragile) for young children. Smartphones are not suitable to track hand movements. Instead, the number of smartwatches and wrist bands on the market has grown enormously and presents a wide range of functions. However, most smartwatches don't have a speaker. As a matter of fact, most smartwatches (in particular, all affordable ones) are built around Android Wear, an operating system for smartwatch which explicitly does not support smartwatch with speakers. The few smartwatches with a speaker such as the Samsung Gear and the Apple smartwatches are, at the moment, still expensive. More importantly, they do not provide a programming interface that allows the development of flexible applications like the one needed.

Finally, many companies are proposing hardware which shares some characteristics with the ABBI circuits (e.g., Arduino Mini or Nano, Xadow). Typically, these companies offer modules which can be combined as a function of the need of the application. However, none of these commercially-available platforms integrate on a single circuit the same set of components, in particular an audio system and communication module. As a result, replicating ABBI with two or three modules leads to device that are significantly bigger than ABBI. Another problem is that these circuits are often not designed to minimize energy consumption while the components mounted on ABBI have been selected for the consumption characteristics and possibility to turn them off when not used.

While the characteristics of the ABBI device are unique to our knowledge, it might be possible to use another device in the future. For example, there are rumors that Google will introduce a version of Android Wear that will support smartwatches with an audio speaker (http://9to5google.com/2015/05/18/android-wear-rumor-speaker-calling/). While the functionalities appear to be limited at the moment, this will certainly encourage companies to build smartwatches with speakers.

Finally, it is worth noting that the HW of ABBI is just the platform on which the habilitation protocols and social support applications are running and that the merging of these two aspects and the assessment of their effectiveness is the important contribution of ABBI whatever means it will be possible to exploit in the future.

At present ABBI has been used for three months by 30 visually impaired children one hour per day and after the use of the ABBI device, children show an improvement of spatial and mobility skills.

Key players and major companies active worldwide in Medical, Game and/or Audio Social Technology Sectors

The following list of companies has been assembled from different report sources:

- Ambutech (CAN, http://www.ambutech.com/);
- Artsana (ITA, http://www.artsana.com/);
- Brevi (ITA, http://www.brevi.eu/);
- Clementoni (ITA, http://www.clementoni.com);
- Foppapedretti (ITA, http://www.foppapedretti.it/it/bambino-technology/sicurezza);
- Amplifon (ITA, http://www.amplifon.it/)
- GW Micro (USA, http://www.gwmicro.com/);
- Handy Tech Elektronik GmbH (D, https://handytech.de/de/willkommen);
- HIMS Inc. (USA, https://hims-inc.com/);
- Hisense Ltd. (ISR, http://www.hisense.co.il/);
- Innovative Rehabilitation Technology Inc. – IRTI (USA, www.irti.net/)
- Johnson & Johnson (USA, http://www.jnjinnovation.com/approach);
- Magnisight (USA, www.magnisight.com/);
- Mayborn Group (UK, http://www.mayborngroup.com/);
- MotorolaHome (CAN, https://www.motorolahome.com/);
- Perkins (USA, http://www.perkins.org/);
- Philips Avent (UK, http://www.philips.com/c-cs/philips-avent.html);
- Samsung (KOR, http://www.samsung.com/us/mobile/wearable-tech);
- Sendero Group (USA, http://www.senderogroup.com/);
- Tiflosystem (ITA, http://www.tiflosystem.it/);
- ViewPlus Technologies (USA, https://viewplus.com/);
- Wicab (USA, http://www.wicab.com/);
- Williams Sound (USA, www.williamssound.com/).

FOR FURTHER READING

- Finocchietti S., Cappagli G., Porquis L. B., Baud-Bovy G., Cocchi E., Gori M. (2015). Evaluation of the Audio Bracelet for Blind Interaction for improving mobility and spatial cognition in early blind children – A pilot study. *37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society. (EMBC 2015)*, pp. 7998 – 8001. **doi**: 10.1109/EMBC.2015.7320248.

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