Explorascope: an interactive, adaptive educational toy to stimulate the language and communicative skills of multiple-handicapped children

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Abstract

Very young non- or hardly speaking children with severe disabilities need active guidance to stimulate interaction with their environment in order to develop their communicative and linguistic skills. Augmentative and Alternative Communication (AAC) systems can help this process, provided that they are tuned to this specific user group. *LinguaBytes* is a research programme, which aims at developing an interactive and adaptive educational toy that stimulates the language and communicative skills of multiple-handicapped children with a developmental age between 1 – 4 years. In this article we show which guidelines we consider essential for developing this tool. We have developed several concepts based on these guidelines, of which we elucidate one called *Explorascope (E-scope).* E-scope consists of a tangible toy-like interface that is adaptable to an individual child with respect to his or her cognitive, linguistic, emotional and perceptual-motor skills. A user test with the first version of E-scope shows that adaptive, toy-like educational tools are promising and useful for this user group.

Keywords: tangible interaction, computer assisted learning, toy design, adaptability, multi-handicapped children

1. Introduction

Problems in the development of language and communicative skills can have grave repercussions to the psychological development of young children, especially with respect to social and emotional maturation and the ability to be self-supporting. According to Heim (2001), the early parent-child interaction and the communicative development during the first years of a child’s life lay the foundations of language acquisition. In the event of severe disabilities, the interaction is not starting or progressing normally, which causes extra stagnation of the communicative and linguistic development. This stagnation can be reduced by scaffolding, i.e. a significant adult guides a child through the Zone of Proximal Development (ZPD) which refers to the gap between a child's existing abilities and what she/he can learn with the guidance of an adult or a more capable peer (Vygotski 1978). Therefore, it is of great importance to enhance and optimise the interaction between parents and non-speaking children and stimulate communication and linguistic usage.

Several tools make use of multi media techniques to support multi-handicapped children and train their cognitive, perceptual-motor, language and/or communicative skills, such as *BioBytes* (Voort et al. 1995), *IntelliKeys* (IntelliTools), *Leaps and Bounds* (Semerc). Despite their success, these and other augmentative and alternative communication (AAC) systems are not tailored to very young non- or hardly speaking children with severely impaired motor and cognitive skills. The cognitive load of these systems is high, i.e. most AAC devices are not organised in ways that reflects how young children think (Shook & Coker 2006). Moreover, the current generation of AAC systems are not particularly appealing to young children in comparison with toys (Light & Drager 2004). They resemble PCs as for structure (menus and decision trees) and/or input (mostly button-like) and output (often screen-based display) (Hummels et al. 2006, in press). Despite the useful endeavour to develop a variety of special input devices, one could wonder why young children are placed behind a desktop computer, which was originally designed for office work. Moreover, PCs are typically designed for exclusive use, i.e. one person sitting behind the screen with input devices, which is far from ideal to enhance interaction between parent and child. In addition, these systems do not capitalise on current technology and multi-media possibilities (Shook & Coker 2006; van Balkom et al. 2002; Hummels et al. 2006, in press), which are aspects that can enhance adaptation to an individual child and offer the possibility to use a variety of strategies to improve language and communicative skills.

A study by van Balkom, de Moor and Voort (2002) shows the necessity of having an interactive training system for this specific user group. The study resulted in a three-year research programme called LinguaBytes[1], which aims at developing an interactive and adaptive educational toy that stimulates the language and communicative skills of multiple-handicapped children between 1 – 4 years old.

This paper describes one of the educational toys that are under development, called ExploraScope (E-scope). We start by explaining the guidelines we use for the development of these educational toys. Subsequently we show what kind of educational toys we are aiming for. Next, we clarify what E-scope is and does, how it is used and how therapists and children perceived it during a user study.

2. Guidelines

After an extensive literature research, we have formulated eight main guidelines for the development for our new educational toy:

- Learn: Our goal is to enable children to improve their language and communication skills by providing them with opportunities to experience and learn about the meaning of new lexical concepts and providing them with possibilities to practice in various ways and at different linguistic levels, coupled to their personal level. The concepts are offered in various ways, e.g. speech, symbols, drawings, photos, movies, objects and text
- Adaptability & personalization: Due to the diversity of children with respect to their cognitive, linguistic and perceptual motor skills and limitations, and their needs and interests, it is beneficial to create adaptive and personalised products. This optimizes the learning settings and avoids frustration
- Technology: Nowadays technological developments like miniaturization, embedded intelligence, sensor technology, wireless networking and rich media, offer a whole new scope of possibilities for innovative adaptive designs, which is not profoundly capitalised on by current AAC systems
- Challenge: Challenge, which is a key element of motivation, engages children by stimulating them to reach for the boundaries of their skills and to take initiative for interaction (Csikszentmihalyi 1990). We aim at challenging multi-handicapped children to capitalise not only on their cognitive and linguistic skills, but also on their perceptual-motor skills
- Playful, tangible interaction: Since we are physical beings we learn to interact with the world through our physical skills, how limited they may be. Therefore, especially with young children that explore the world through play, we focus on playful, tangible interaction in accordance to current trends in toys
- Independence: Feeling independent is an essential part in the motivation of children while learning. Independence gives the feeling of being in control, which enhances the satisfaction of reaching goals. This demands much of the intuitive quality of the product
- Teach & monitor: Next to children, the system will be used in cooperation with therapists and parents. We aim at an educational toy that evokes communicative and social interaction. Moreover, recording and displaying performance data of a child in a user model enables therapists and parents to gain a clear understanding of the progress of that child and adjust their strategy accordingly, if not done already automatically by the adaptive system
- Frame of reference: Finally, we like to base our design on the children's mode of living and the way they perceive their environment in order to inspire them, and stimulate their imagination and curiosity

With these guidelines we aim at a system that enhances the self-confidence of non- or hardly speaking multiple-handicapped children between 1 – 4 years old and that stimulates them to learn.

3. Our approach

Based on the guidelines, we are designing several concepts through a research-through-design approach, i.e. through the act of designing resulting in experiential prototypes, and subsequently testing these prototypes in real life settings, we generate scientific knowledge (Pasman et al. 2005). In this case we generate knowledge about novel, adaptive & tangible AAC systems for improving language and communication skills, which has to result in a theoretically and experientially sound product.

When we design interactive products, the process typically moves through several cycles of designing-building- testing, in which each iteration refines the product. The iterative design process of LinguaBytes consists mainly of two phases: conceptualisation and specification. During the conceptualisation phase, we explore the scope of the new tangible tool, by building and testing a comprehensive set of concepts / prototypes. The most appropriate concept will be further developed, completed, built and extensively tested during the specification phase.

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The first conceptualisation round of LinguaBytes started in 2004 with E-scope, which will be further explained in this paper. We have just finished the second round of the conceptualisation phase, which consisted of building and testing four simple concepts based on interactive books, prints, and tangible objects.

We are currently in the third round of this phase in which we are building and testing two interactive tangible sketches of educational toys (see Figure 1). The conceptualisation phase will end with an extensive long-term user test of a full working prototype of the final concept, which is based on the findings of the first three rounds. It goes beyond the scope of this paper to elaborate on all rounds; we will only focus on the first round: designing, building and testing E-scope.

Figure 1 Ring-based design (upper left), InteractBook (upper right), PictoCatcher (lower left) and ObjectSlider (lower right).

E-scope is a ring-based design that can trigger an auditory play by rolling it across a drawing or activate a movie by turning the upper ring and pushing buttons (Figure 1, upper left). InteractBook plays a sound file after turning the page (short story/sentence) and when touching the depicted PCS symbols (related word) (Figure 1, upper right). PictoCatcher is an interactive marble course where each marble with an enclosed PCS symbol is related to a story and triggers a movie when entering the wooden box (Figure 1, lower left) and ObjectSlider starts or alters an animation by placing the related tangible objects next to the screen (Figure 1, lower right).

4. E-scope: an adaptive tangible controller

In the remaining part of this paper, we explain E-scope, a tangible controller that enables young children to learn simple concepts (e.g. sleep, clock, bear) through tangible interaction and play.

The prototype of E-scope consists of a wooden ring-shaped toy with sensors and actuators, a computer with a wireless station and a screen (see Figure 2).

Figure 2 E-scope consists of a wooden toy, a computer with a wireless station and an optional separate monitor (left). The upper and lower ring of E-scope communicates with the computer through radio transceivers (right). All sensors, actuators and batteries are built into the layers of E-scope.

Figure 3 E-scope configurations: Using pictures (upper left); integrated LCD screen (lower left); with separate screen (centre), or with a variety of input devices making it possible for a severely motor handicapped person to operate it (right).

E-scope is adaptable to a child and can be used in different configurations (see Figure 3). A child can listen to stories or play educational games by rolling E-scope over pictures that are lying on the floor. Every picture triggers a matching story. The buttons can be used for further deepening of the concept. E-scope can also be used on a table. By turning the upper ring and pushing the buttons on the wooden ring a child can interact with stories shown on an integrated or a separate screen, depending on the ergonomic and social requirements. If necessary, E-scope can also be attached to alternative input devices, for e.g. one button or eye-movement interaction. In this last case, the upper ring is rotated by use of a motor. The different configurations all require a different level of motor skills and have different social impact. Moving the E-scope over the floor is suitable for children with gross motor difficulties, but with the ability to move their entire body by crawling and gliding. It is a very playful and informal way of interacting, especially when the therapist is also sitting on the floor. Children with gross motor difficulties and who have less control over their entire body can push an additional big button. Turning the upper ring requires more control and coordination between both hands and pushing buttons requires fairly fine motor skills of at least one hand. The position of the screen has next to ergonomic aspects also clear social implications, because it determines how the therapist and child are positioned in relation to each other. Not just the way of interaction is adaptive, but also the complexity of stories, which means that children of different cognitive levels can use E-scope. In the early developmental stages, the stories use simple concepts and are self-running. After that, the child could learn to push buttons and attach meaning to the colour of that button, which is linked to specific actions in the stories. Finally, the child could learn symbol systems such as Picture Communication Symbols (PCS) that are printed on a ring that can be placed on E-scope. This ring is recognised by the computer using photo-interrupters and linked to the related stories, see Figure 4.

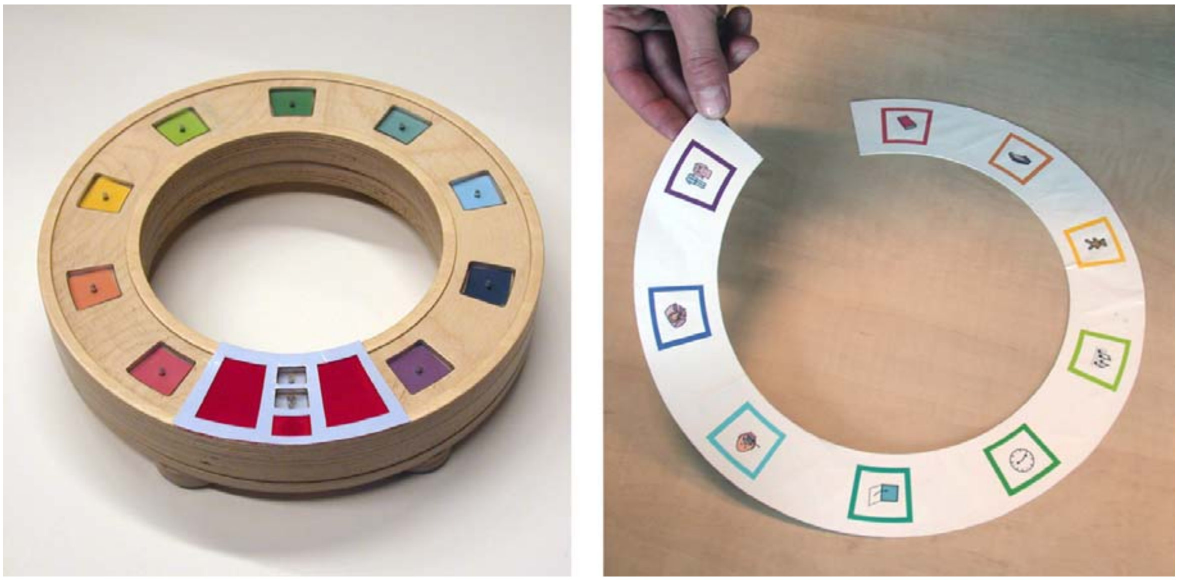

Figure 4 E-scope can be used with or without symbols

5. Multi-media content

The stories that are offered by E-scope aim at being rich and engaging. Therefore, they use a variety of visual and auditory output such as photos, drawings, movies, symbols, spoken stories, sounds, songs and written text. The graphical style aims at being realistic for an optimal recognition of the concepts to be learned, but which enough freedom to stimulate the imagination of the children (Figure 5). A small user study with two children indicated a preference for photos compared to drawings.

Figure 5 Different graphical styles: photos (left –to-right, 1 and 3) and drawings (2 and 4).

For children who have problems with attachment and recognition, such as autistic children, child-related photos can be imported and voice and sound recordings can be made with E-scope. Therapists and parents can also use this option to focus on a specific or actual topic, such as telling the story of a day with pictures of that child's environment or the birthday of a family member. Using a built-in menu, which is operated through the upper wooden ring, one can customize the E-scope. By turning this ring, one moves through the different screens, as if they were placed behind each other. If the desired screen is shown, it can be selected by pushing one of the buttons. This brings the user to the next menu levels, which can be browsed through in the same way. By turning the ring to the right, one goes deeper into the menu, and by turning to the left one goes back up again (see Figure 6). Extra feedback is given through LEDs and sound.

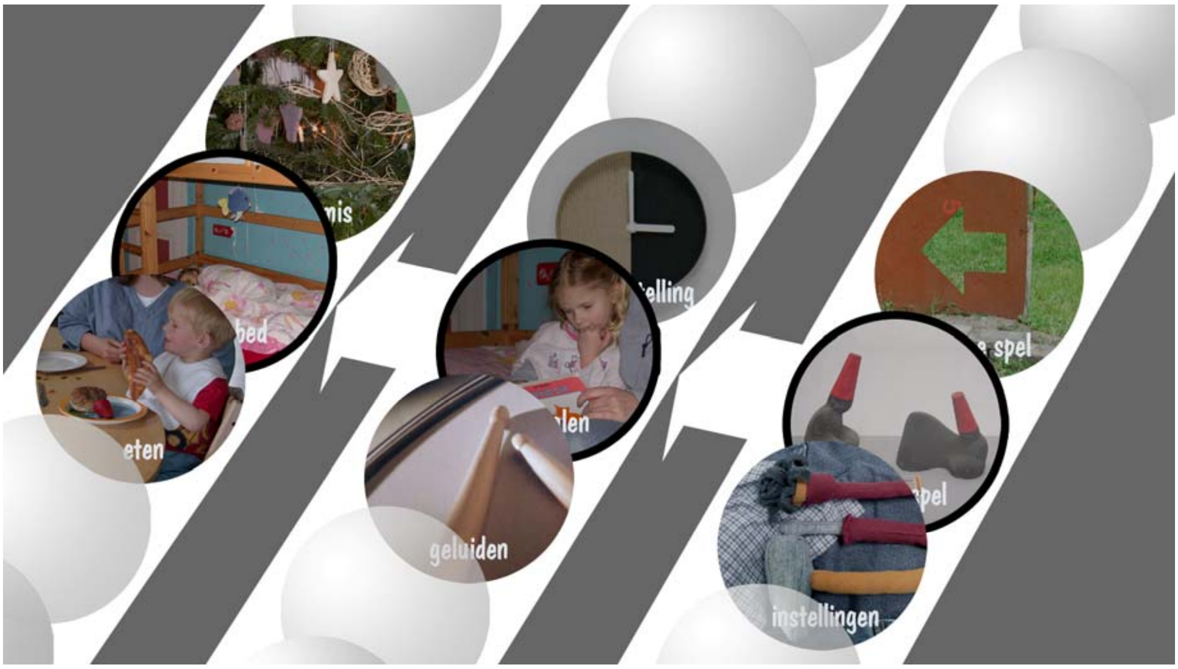

Figure 6 E-scope upper ring turns through the menu screens

By turning the upper ring the user goes through the screens of the menu, as if they were placed behind each other (Figure 6). On the first level one can select the overall functions like preferences, choice game and previous game (Figure 6, right). If one selects 'choice game' by pushing an arbitrary button when this picture is displayed in E-scope, one gets the different options for the second level (Figure 6, middle), for example sounds, stories and contrast. When selecting e.g. 'stories', one can choose different stories like eating, going to bed and Christmas (Figure 6, left images).

6. E-scope prototype

To develop a working prototype of E-scope we designed software architecture with three subsystems, briefly discussed in the next sections and illustrated in Figure 7.

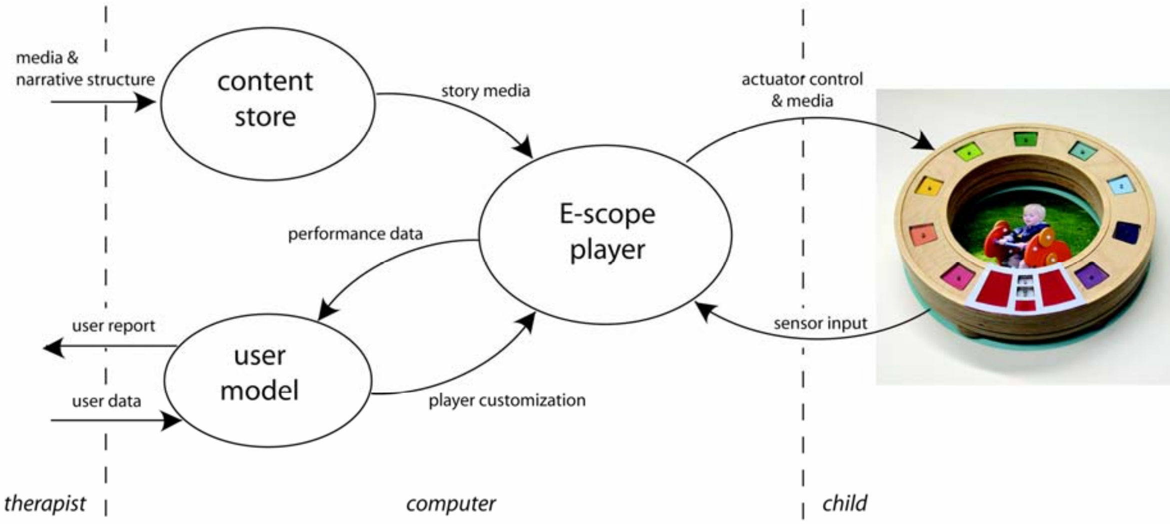

Figure 7 System diagram

6.1 The content store

The content store is a collection of stories and games. The scripts for the narratives are developed based on literature on the linguistic development in the first years of a child's life (van Balkom et. al. 2002). From these scripts, all elementary content material like photos, movies, drawings, spoken text, etc. are created and imported into the content store.

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The next step involves linking these elements into narrative structures like arranging the pages of a story. Then the conditions for page transitions are defined; these are coupled to specific actions on the tangible controller, e.g. a button press. The conditions can also be seen as educational targets, the reward for pressing the right button is getting to the next page.

For example, within the story *"Jitte goes to bed*", the first page consists of:

- A picture of Jitte who is tired (see Figure 5)
- A sound file with a voice saying: "Jitte is tired, she wants to go to sleep"
- And the condition: move to the next page once page is presented

The second page consists of:

- A PCS icon of the word 'sleep'
- A sound file with a voice saying "sleep"
- A picture of the words 'sleep' in text
- And the condition: wait for button press of button showing the PCS icon 'sleep'

By placing these files in the content store and after assigning links and conditions, the final story that will run on E-scope can have the following outcome:

> E-scope starts by saying, "Jitte is tired, she wants to go to sleep" and meanwhile showing the photo of Jitte lying on the couch.
>
> Subsequently, the system automatically starts page 2 and the voice is saying, "sleep" while showing the PCS icon of 'sleep' and with the text 'sleep'.
>
> Now the child has to push the 'sleep' icon on the ring, or any button when no PCS icons are used, or even no action at all when the E-scope is running in automatic mode.
>
> The word 'sleep' is repeated again and subsequently the following scenes appear until the entire story with nine scenes is played.

Therapists and parents can add to the content store with stories tailored to the needs of an individual child, although the majority of stories will be imported beforehand. The current version has two stories 'Jitte goes to bed' and 'the children's farm'. Only after having tested the different concepts (e.g. E-scope, PictoCatcher and ObjectSlider) and having decided upon the chosen concept, the stories and games will be further developed.

6.2 The user model

E-scope can adapt content browsing to the physical capabilities, knowledge level or concerns of the child through the user model subsystem.

The system can also record performance data in the user model to enable the therapist to gain insight into the progress of a child. For example, the first time when the child uses E-scope, a profile has to be made, stating the level of motor skills (ability to push buttons, use of specialised input devices, preference to use at a certain place etc.), the cognitive and linguistic level (vocabulary, pronunciation, mental development, mastering of certain games etc.), attitude (level of independence, social interaction, level of communication etc) and personal concerns (preferred graphical style, hobbies, preferred subjects etc.).

6.3 The E-scope player

E-scope can adapt content browsing to the physical capabilities, knowledge level or concerns of the child. The E-scope player subsystem is tightly coupled to the content store and the user model. The E-scope player interfaces the tangible controller and detects the configured page transition conditions, upon which it schedules the playback of content on the next page and updates the user model to reflect the progress made. For example, if the child has a fairly low linguistic developmental level and rather fine motor skills, the E-scope player subsystem can decide to use the coloured buttons and show the next page when an arbitrary button is pushed. When the child is not responding and no button is pushed within 5 - 10 seconds, the E-scope can give a hint on the screen or through its LEDs or speech.

7. First user test and conclusions

The current version of E-scope a not a fully implemented product, but a prototype to enable us to evaluate the interaction with it, the playfulness, the general impression, and get feedback for further development. This first version of E-scope was tested with three children and three therapists in the Rehabilitation Centre St. Maartenskliniek in Nijmegen, The Netherlands. E-scope was explained to the therapist before the actual therapy began. Two children used the '*Jitte goes to bed'* story, one on the table and one with help from the therapist on her wheelchair, and one child used the '*the children's farm*' story on the floor (see Figure 8). Each session took half an hour and was conducted during a 'regular' speech therapy session. The sessions were annotated by an observer on the spot and also videotaped for further analysis afterwards. The therapists were interviewed after their session with respect to their general impression, feasibility of the concept, challenge, playfulness, the support for learning, tangibility, the suitability for teaching, connection frame of reference of the children and graphical style.

Figure 8 Therapists test three children with E-scope

Figure 8 shows E-scope being tested by three children with their therapists. Child 1 (left) preferred using an E-scope with an integrated LCD display. Child 2 (middle) was persuaded to listen to short stories by rolling the E-scope over large drawings that were lying on the floor. Child 3 (right) preferred moving the E-scope across the table, turning the upper ring and pushing the Picture Communication Symbols (PCS) on the wooden ring to hear and see stories on a separate screen. The test indicated that the overall concept is promising and useful. The therapists were very positive about the toy-like appearance and its playful, engaging and sensorial character. They were enthusiastic about the diversity of interaction style and multi-media output, thus supporting different strategies and skills, which is hard to do with the currently used methods and tools. Moreover, the therapists preferred further adjustments to improve the personal fit. For example, the therapist from child 1 would like to use E-scope with an integrated motor that can be operated through eye-movements.

Working with a novel toy and two observers was a bit too much for the autistic child 2. His therapist advised us to enable his family creating their own, familiar content (images from home and speech from his parents). Moreover, if child 2 could get familiar with E-scope by using it frequently as a regular toy, e.g. a musical instrument; it could help the speech therapy with E-scope. The therapist from child 3 wanted an integrated screen to enhance social interaction by sitting opposite each other with E-scope in the middle. The children gave a similar impression when looking at their behaviour. The two girls were very enthusiastic. Child 1 was clearly excited by the stories and graphics, and seemed to feel enjoyment during interaction (laughing frequently) and she had a proud look on her face after having selected the correct PCS symbol several times. The toy amazed and captivated child 3 who had her eyes wide open and who was showing a beautiful concentration. The tangibility of the toy challenged her to push the buttons frequently and she was delighted to receive the movies as a kind of reward. Child 2 was very restless and was overwhelmed by this deviation from his regular routines. However, despite this behaviour, he immediately understood the working of E-scope and interacted with it frequently. E-scope will be further developed in the near future and tested again with children. The findings of the studies are used to enhance the development of other concepts. The results of the overall conceptualisation phase will be an extensive user study with a full-working prototype.

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