MEDIATE: An interactive multisensory environment for children with severe autism and no verbal communication.

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Abstract

The design of an interactive system for children with severe autism and no verbal communication is one of the most challenging areas a designer of interactive systems can approach; mainly because of the exceptional type of user involved. In fact, this user cannot be typified because autism is not a unique disability but rather a spectrum of disabilities. Moreover, non invasive systems must be designed, new approaches for real time generated stimuli must be analysed and developed, and new developing strategies must be imagined for such interactive systems,

Keywords

Real time generated stimuli, environments, CHI, interaction-driven design, gestalt theory, autism.

1. Introduction

MEDIATE (A Multisensory Environment Design for an Interface between Autistic and Typical Expressiveness) is an interactive environment that generates real time stimuli (visual, aural and vibrotactile) such that low functioning children with autism, who have no verbal communication, can hopefully express themselves and "have a bit of fun". This goal, in spite of its apparent simplicity, is actually quite demanding and ambitious, both in psychological and in technological terms. This is why it must be stressed that this environment does not pretend to be neither therapeutic, nor educational. In spite of previous attempts by other research projects to work in this direction ([Strickland, 1996][Strickland, 1997][Dautenhahn, 2000][Workshops, 2001, 2002]), psychologists in the consortium believe that our understanding of autism does not yet permit to aim for such ambitious goals, especially in low functioning PAS (persons in the autistic spectrum).

MEDIATE is a project under the FP5 / IST / Systems and Services for the Citizen / Persons with special needs (including the elderly and the disabled) lasting for thirty months. It is co-ordinated by the "Responsive Environments Centre" of the "School of Art, Design and Media" of the University of Portsmouth (U.K.). The rest of the consortium is composed of: "Faculteit Kunst, Media and Technologie" of the Hogeschool voor de Kunsten Utrecht (Hilversum, Netherlands); the "Institute of Psychiatry" of Kings College London (U.K.); Show Connections Limited (Crowborough, U.K.) and the "Experimentation on Interactive Communication" group of the "Audiovisual Institute" of the Universitat Pompeu Fabra (Barcelona, Spain).

In this paper we will describe the design approach, functionality and results of the project, from the point of view of the visual interaction design, defined by the team at Universitat Pompeu Fabra.

2. What is Autism?

Autism is a set of disorders in intercommunication and interrelation abilities that lead to an impairment of cognitive and emotional development. The essential characteristics of this disorder are the presence of an abnormal development in the following areas:

- **Communication**: Difficult or inexistent verbal communication. Difficulties in non-verbal communication.
- **Socialisation**: Severe difficulties in interpersonal relationship.
- **Imagination**: There is a lack of imagination characterised by uncommon and repetitive game play.

This is externally manifested in a lack of affective expression, an apparent lack of empathy, an obsessive concentration on particular elements and, often, repetitive movements. The factors that determine autism have a biological cause and the disorder is manifested during the first thirty months of the child. At a cognitive level, there is a weak central coherence [Happé, 1999] that impairs an adequate integration of the stimuli that surrounds the child. The three main characteristics mentioned above, make the child unable to discriminate between and, more importantly, predict, any of the events that occur in daily life. Hence, this unpredictable world is felt as alien and makes them feel isolated. Technically it is said that they have no sense of agency; i.e. they have no sense of connection between them and the surrounding world.

There are huge differences among individuals that are placed at different levels of the wide spectrum that goes from low functioning to high functioning. MEDIATE is designed for children between 6 and 12 years of age; low functioning persons in the autistic spectrum (PAS) with no verbal communication abilities.

3. What does the MEDIATE environment look like?

MEDIATE is a hexagonal space, approximately six meters in diameter. Inside the space several elements act as interaction interfaces (Figure 1):

- the floor surface: it reacts to footsteps generating sound.
- the tune fork: a wall with tube-like structures that generate sound when caressed or stroked
- the screen walls: two rear projection screens (300 x 225 cm) are the support for visual interaction that react to the child's movement and touch.
- the impression wall: a wall with padded structures that react to pressure and emit vibration.
- the sound interface: a set of microphones and speakers that react to sounds emitted by the child in the space (voice, clapping, etc.).

4. Goals of MEDIATE

Previous work from the University of Portsmouth, mainly interactive sound installations for the general public, had informally proven very exciting for children with learning and cognitive disabilities, including some children with autism. This led them to contact the Institute of Psychiatry to get some professional assessment by leading researchers in autism, who in turn explained that there was some evidence that audiovisual/digital media are attractive for these children. From this union, together with the other partners that gradually joined the group, a main goal and two secondary goals were defined:

- Main goal:
    - For the children with autism to have fun and have the chance to play, explore and be creative in a predictable, controllable and safe space.
- Secondary goals (completely subject to ethical considerations):
    - For the psychologists to better understand autism and the possible underlying communication mechanisms.
    - For the parents of the children with autism to find new qualities in their sons or daughters by seeing them play in this environment.

5. How to reach these goals?

The consortium defined four strategic concepts with which to achieve the main goal and the two secondary goals. These are defined below:

5.1. Control to achieve a sense of Agency

As stated before, autistic children rarely experience a sense of control with respect to their surrounding environment. Because of the multiple layers of stimuli in our world, they cannot understand why events around them occur, even in the cases when they themselves are causing these events.

Therefore, one of the basic concepts behind the design of MEDIATE was to provide the user with clear interaction dialogues that would hopefully give the children a sense of control of the system. If this was achieved then they would probably gain the sense of agency that makes them feel at ease.

5.2. Enhance Non-Repetitive Actions

Children with autism often fall into repetitive attitudes like rocking movements or flapping an arm or a hand. They tend to do so when they are feeling overwhelmed by the surrounding stimuli. Apparently these *stereotypical movements* help them isolate themselves from the environment and feel at ease and relaxed. They can also be very repetitive in their actions when they are obsessed by something they like doing and hence do it over and over in an overexcited manner. Both attitudes are considered undesirable by psychologists, because they isolate the child from the world. Therefore, the second concept behind the design of MEDIATE was to detect repetitive patterns in any of the sensed attributes of the user. A part of the "brain" of the system is therefore in charge of recognising these repetitive sequences at different time scales (from half a second to fifteen seconds) and informing the rest of the system in order to try to pull the child out of this state.

5.3. Adapt to each Child

Because of the wide spectrum of children with autism that could use the environment, the consortium thought it would be important to make the system adapt to each child's needs and potential. This way, the consortium designed a "decision maker" module in the brain of the system, such that if the child was behaving in a *novel* (i.e. non-repetitive) manner, the environment could raise its complexity to make the interaction richer. This increase in the richness of the interaction starts within each modality and eventually can evolve into an intermodality mode where the different stimuli (image, sound and vibrotactile) will start affecting each other. If on the other hand, the "decision maker" is informed that the child is behaving in a repetitive manner, then the environment begins to dim down all responses making everything drop back to a less demanding or softer interaction mode.

5.4. High Functioning Children in Design Team

To be able to determine whether the design decisions were on the right track, groups of high functioning children with autism, who can give verbal feedback, were incorporated in the design teams, at each participating

university, as informers. They gave useful comments on the type of stimuli being designed and the type of interactions proposed.

6. Why an Environment?

The project could have been developed as an interactive object rather than a space. The object approach, though, could have made the children obsessed by this object or could have made them become more isolated. This would have made it difficult to evaluate whether the experience was successful for them. Another option would have been a desktop system, but the interaction rules would have been too difficult.

The environment approach was chosen because the children could very easily adapt to a full body interaction. By simply moving through the defined space, the environment could already start responding, opening small doors that could lead the child into playing with it. But also many other basic body behaviours like gesticulating, touching, leaning, pressing, screaming, clapping, etc., could be picked up and used to start the interaction dialogue. In order to make this possible, the environment is composed of, on one hand, a set of sensors that capture de user's actions and, on the other, a set of software that generate the response stimuli based on what we call *interaction models*. An essential precondition in the design was the use of non-invasive sensors. This implies that no sensors or cables could be placed on the user. We could not even consider the child wearing markers nor dressing in any specific manner. Hence the sensors are all external: microphones, cameras, transducers and pressure sensors, that are distributed throughout the environment and that are analysed and managed by the computer system in real time.

7. The User: Cannot be typified!

When designing an interactive application, one of the first basic steps is to analyse and define the type of user to which the application is addressed; i.e. the user must be typified. In our case though, because the spectrum of disorders in autism is so wide, we had the imposed restriction of not being able to typify our user. Hence, we have had to establish new strategies or adapt the procedures commonly used in interaction design. This has been our main challenge and interest in our research group.

We shall now focus on the design of interaction with visual stimuli for MEDIATE, done by the Experimentation on Interactive Communication group (EIC) of the Universitat Pompeu Fabra, as an example of how the user could not be typified, how we had to design interaction and how we somehow needed to decide which stimuli design to use.

8. Interaction with Visual Stimuli Design

As we have mentioned, the common procedure in the design of interactive systems is to start by defining the type of user and application, then the data or contents that the user will need and the processes involved, and finally the interaction and the interfaces. Because we could not typify the user for MEDIATE, a new approach was needed.

The EIC group had formalised in previous artistic VR projects the *Interaction-driven* design as opposed to a content-driven or user-driven approach [Pares, 2001a,b,c].. Thus, we started by identifying the input/output interfaces, we then defined an interaction model and finally defined the type of application and visual elements to be used.

Because the consortium had decided upon a full body interaction, we decided we had to find basic and general body behaviours that could easily cause a reaction in the system and that would be clear to the user. These very simple behaviours that any child should be able to do were: move laterally in relation to the screen, move towards the screen or away from it, gesticulate in front of the screen, touch or lean on the screen, etc. This allowed us to start thinking of very simple games to play with images like making them appear or disappear, making them grow or shrink, make them mimic the user, etc. With these simple interactions, the user would

hopefully understand she is in control of the situation. But we still needed to know which type of images to use or which image strategy to follow.

9. Theory of Visual Perception: Gestalt Theory

When we started to design the interaction with visual stimuli, we began to ask ourselves questions such as: will these children be afraid of dark spaces? Will they be overwhelmed by too much light? Do they prefer certain colour gamuts? Do they understand images for what they represent? Or rather, do they see only shapes and colours within an image? Do they prefer abstract or representational images?

All these questions were posed from the gestalt theory; i.e. the theory of perception and understanding of images by humans. But the answers given by the psychologists to these questions were always: "there is no literature that gives evidence that they prefer any of those options" or "there is no evidence that they interpret images in any particular way". This of course did not help us in typifying our user and left too many options open.

One thing was very clear, though, the consortium wanted the children to accept the environment because of the sense of control gained through the proposed interaction, ruling out the possibility of accepting the environment based on specific content presented within it. What this meant in the visual stimuli context, was that, if for example we placed the image of a dog (or a virtual dog) within the environment and a child had had a bad experience with dogs in the past, then the environment would be a failure for that child because of that single identified object. Similarly, if a child loved dogs, then the environment would also be a failure because the child would be fond of the environment mostly because of the dog and not because of the interaction dialogue proposed. Or even worse, the child could become obsessed by the dog and forget about the rest of the environment. From this reasoning, we decided to work with abstract or non-representational images. But which type of images should they be?

10. Particle systems

In our search for visual design, we found that children with autism have difficulties integrating parts of objects into complex objects. For example, when a child with autism is given a toy car she will probably play with the wheels by making them spin with her finger, but she will not understand the whole object and its functionality, hence will not use it as a toy car. On the other hand, we also found that children with autism are very fast at finding a shape hidden in a mesh of lines, whereas neurotypicals (non-autistic people) take quite long in finding them.

Because of these two issues, we thought of working with isolated geometrical elements and this immediately reminded us of particle systems (see for example, [Foley, 1990]). We thought that each particle could have its own particular behaviour, or the whole group of particles could have a group behaviour, or the group could have a global behaviour that came from the sum of individual behaviours. We also thought that particles could be individual isolated elements, or they could be grouped to form larger objects, or they could be spread out forming a background, or even leave holes in this background where each hole is in fact a shape. So how could we get the children to start playing with the particles?

11. Interaction Models

We designed up to eleven interactive games with particles, from which we chose four to be fully developed as preliminary work in the process of obtaining the final visual interaction for MEDIATE. These interactive games we called *interaction models* because they not only set the rules of a game, but also define a philosophy behind the game that states what we are looking for in the child's play. We will now describe the four developed interaction models:

11.1. *Ta-to-mo* (Come close – Touch – Move)

We have a screen fully "tiled" with large square particles. When the user moves, the particles rotate to orient themselves towards the position of the user. The user's distance from the screen affects the size of the particles (when close they grow, when far they shrink). On touching the screen a wave of colour is generated from that point outwards (Figure 2).

11.2. *Fullaraca* (Leaves)

Fullaraca proposes a game where full body interaction is extremely important, both in moving around and in body gestures (legs, arms, etc.). The lower part of the screen is full of particles, like leaves that have piled up on the floor. When the user passes in front of the screen the particles are thrusted up as if by air currents. When they lose energy and fall they can collide with the projection of the user and collect around to the user's silhouette. If the user is passive the system makes invisible "gnomes" appear, moving through the piled particles, shaking them slightly to make the user curious and hopefully make her become active (Figure 3).

11.3. Kite

Kite gives priority to "gestures"; the idea of drawing in the air. One particle is differentiated from the rest (the "kite") following the user's hands and/or body. The rest of the particles are scattered through all the screen. As the "kite" moves through the screen and passes over the other particles it picks them up and places them at the end of its "tail", hence the tail grows longer the more the user plays. If the user stands still, the particles of the tail begin to leave it, starting from the end, and go back to their original position in the background (Figure 4).

11.4. *Traç/en* (Traces)

This proposal tries to empower visual integration through small movements of the user (hands, head, etc.) and to achieve this it distinguishes them from large movements through space. A cloud of particles moves across the screen. The large movements of the user cause the cloud to change direction. The small movements of the user "freeze" a group of particles in front of her forming an object that falls to the bottom of the screen. After a while, the object is "eroded" by the cloud that swallows back its particles (Figure 5).

11.5. The Final Interaction Model: *Mo-ta-to* (Move – stain me – touch me)

Some of the preliminary interaction models were found to be inadequate for children with autism thanks to the information given by the high functioning children that helped in the design and to the psychologists' comments. For example, "Leaves" was not considered contingent enough, i.e. the feeling of control was not sufficiently clear because the particles seemed to have a "life of their own". Kite was considered as demanding too much motor control of the user as many low functioning children have motor difficulties.

The final interaction model we defined for MEDIATE takes some of the aspects that seemed most successful from some of the preliminary models and picks up some of the suggestions made both by informers and psychologists.

This final interaction model is based, as *Ta-to-mo*, on a screen tiled with square particles. Initially though, the screens are empty, only coloured with an initial colour that sets the interaction gamut. When the child enters the environment, the system detects her presence and presents a grid of small tiled particles. This is already a very effective small and basic game that many children have successfully discovered and enjoyed. The particles grow as the user comes closer to the screen and shrink as the user moves away. There is a gradient in size and shade of colour of the particles from the user's position to the edges of the screens, creating a constant sense of shelter wherever the child moves to. When the child is in front of the screen, the particles that fall within the area of what would be her projected silhouette, grow and join to create a blocky silhouette. The movement of the silhouette is done by interpolating the growing and shrinking of the particles, thus giving a sense of gelatinous material. This gives interaction a very fluid feeling. Finally, if the child comes very close to the screen and/or touches it, a wave of colour is generated starting from the touched point outwards (Figure 6).

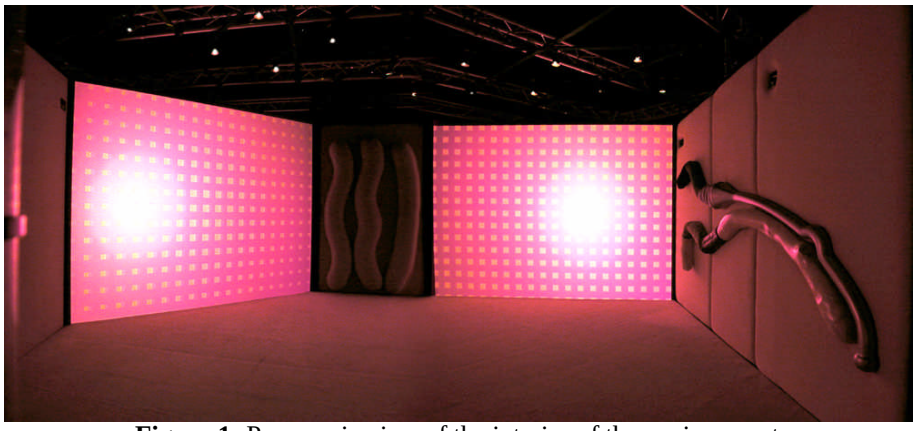

Figure 1: Panoramic view of the interior of the environment

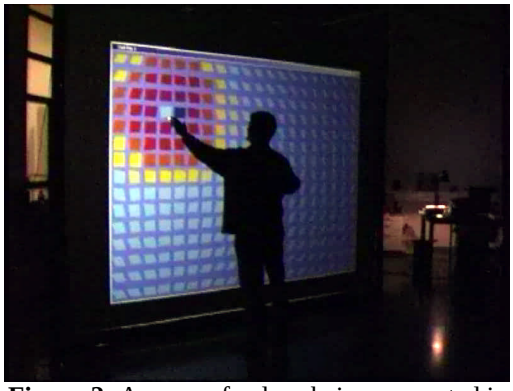

Figure 2: A wave of colour being generated in *Ta-to-mo*

Figure 3: The silhouette of the user is revealed by the particles (leaves) that are blocked by it.

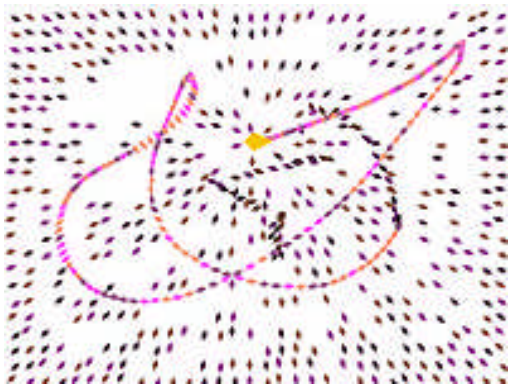

Figure 4: The tail of the kite makes the trace of movement of the user visible.

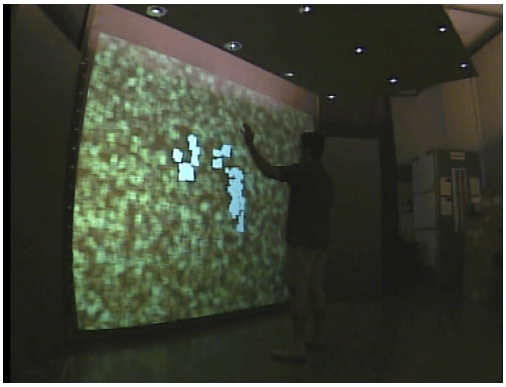

Figure 5: The small movements of the user "freeze" particles that join to form objects.

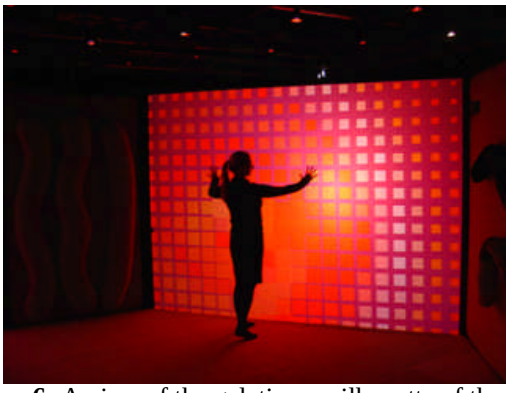

Figure 6: A view of the gelatinous silhouette of the user.

12. Results

MEDIATE is a dismountable and transportable environment and sessions with children with autism have been held in London (Goldsmith's Institute, Kings College) during two weeks, in Hilversum (Hogeschool voor de Kunsten Utrecht, Netherlands) for five weeks and in Barcelona (Universitat Pompeu Fabra) for four weeks that have just now ended (February 14). MEDIATE will now go to Portsmouth and will be holding sessions with children during six more weeks. When all the sessions have finished, the psychologists of the team will make their formal evaluation of the sessions of approximately 60 children, and we will have official results towards the end of May.

In Barcelona eleven children have participated in MEDIATE, each having three sessions in the environment. Hence thirty-three, two hour, sessions have taken place here. The partial results are that only one girl did not want to enter the environment on her first visit. On her second visit she had no problem to enter and play. The rest of children played to a greater o lesser degree, but had no problem entering. Needless to say that the children are not in any way forced to enter. In fact, the psychologists ask the parents (who are present during interaction just outside the action space) not to push (neither physically nor verbally) their children to enter the environment. This is already a huge success for the environment, because children that need very rigid daily routines and that do not cope well with unknown places, have actually become curious enough to enter on their own will and start playing. The time spent in the environment varied from 5 minutes to 35 minutes. In every case, it was clear that the children found at least one of the proposed interactions and successfully played with it. None of the children experienced discomfort in the environment and only one of the sessions had to be stopped because of the child's overexcitement.

Now it is the psychologists task to evaluate whether the children acquired the sense of control within the environment thanks to the designed interaction. It will also be important to know whether the children were feeling at ease during the sessions and engaged in the interactions. The only answer that is really needed is whether they had fun in MEDIATE.

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