CareToy project

A Modular Smart System for Infants' Rehabilitation At Home based on Mechatronic Toys

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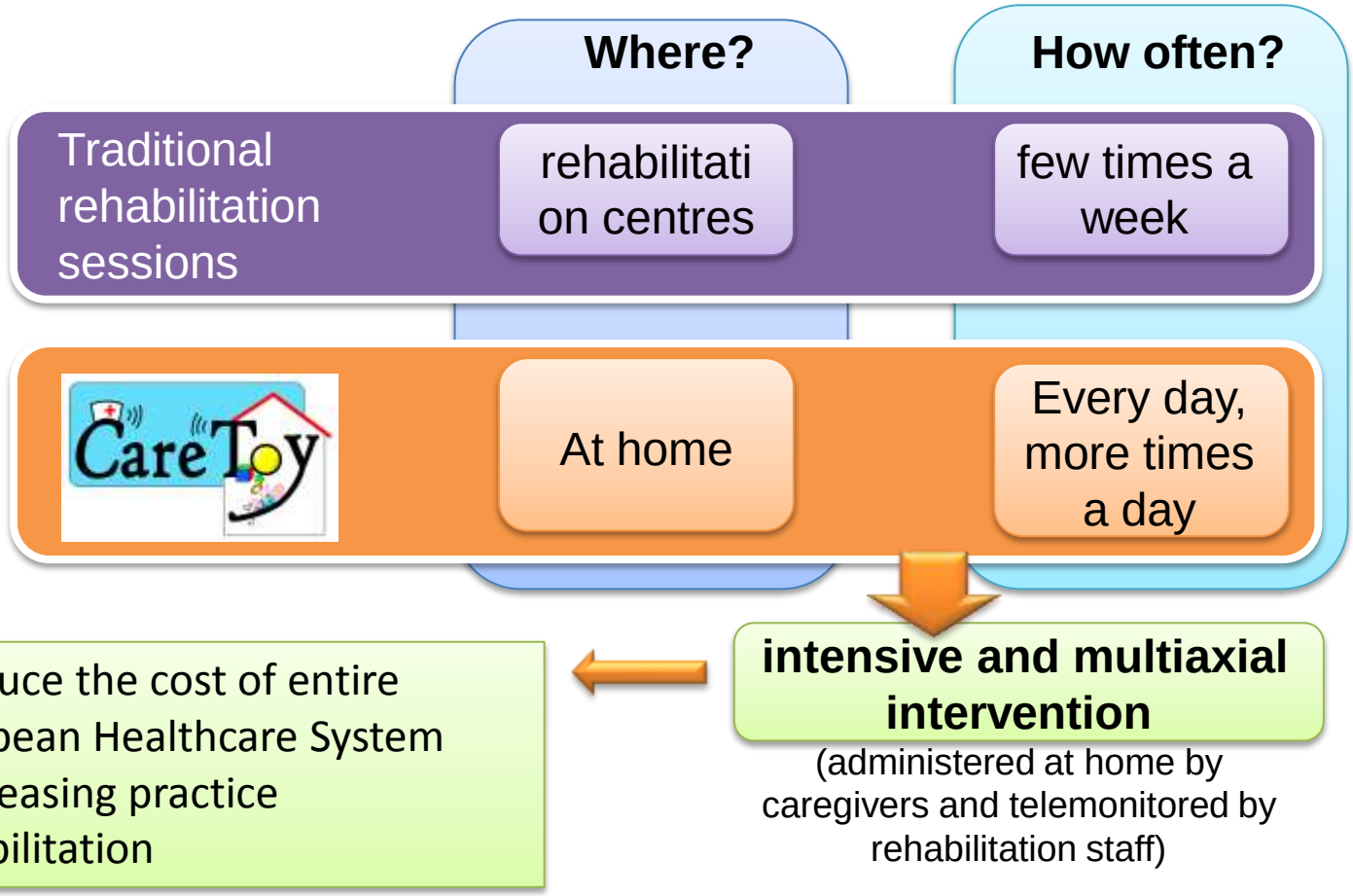
Workshop on new multi-sensor devices for remote management of disease
Hamburg, Germany, September 15, 2012

Outline of the talk

- CareToy framework: Stroke and early intervention
- CareToy objectives
- Proposed platforms: CareToy and CareToy H
- CareToy H modules
- Example of experimental scenario

CareToy Objective and Distinctive Features

- Stroke and other neurological conditions affect the population of infants in percentages that cannot be considered marginal.
- Preterm infants are the highest infants at risk for neurological damage.



CareToy objectives

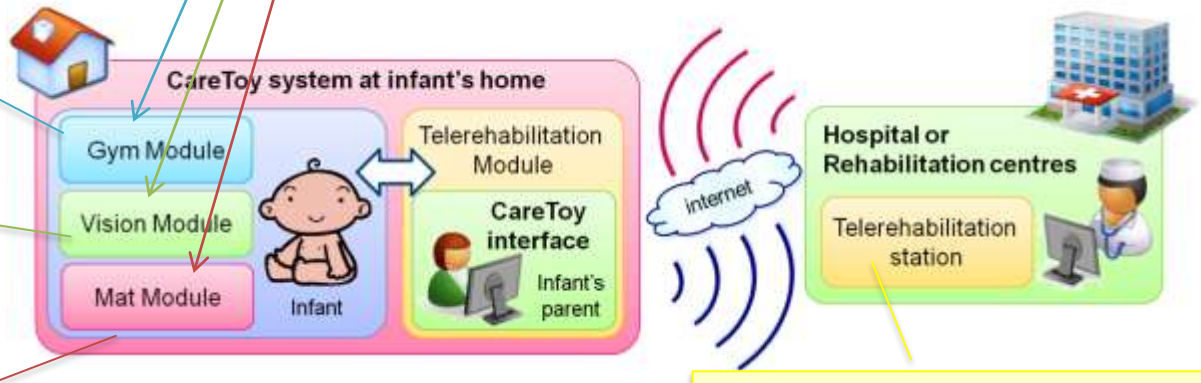
- To measure and stimulate 3 main functions:

1. infants' grasping forces,
2. Infants' gaze,
3. Infants' postural control

with mechatronic hanging toys

for measuring and promoting infants' attention and gaze movements

measuring and promoting postural control



remotely communication with the rehabilitation staff for monitoring and assessing the efficacy of rehabilitation techniques

The two CareToy systems

- In relation to the **2 main aims** of the project
  - *Assessment*
  - *intervention*

→ 2 different systems designed and developed

2 systems

CareToy C

- Clinical environment
- for the **assessment** purpose

6 systems

CareToy H

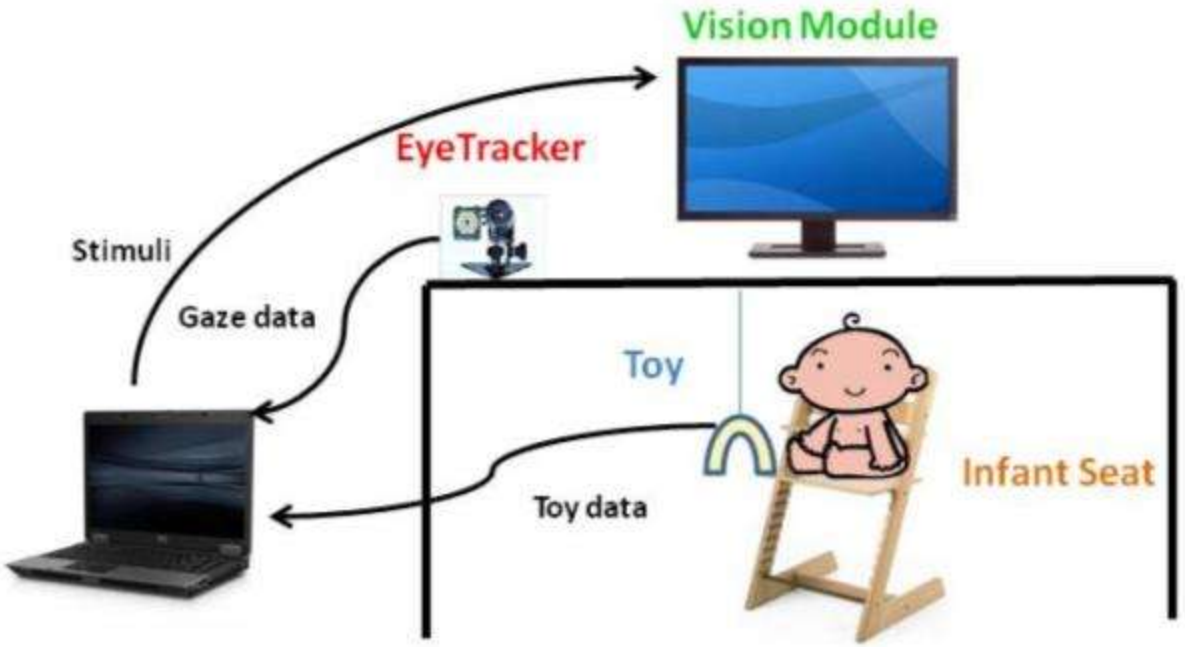
- Home
- for the **intervention** process.

CareToy C

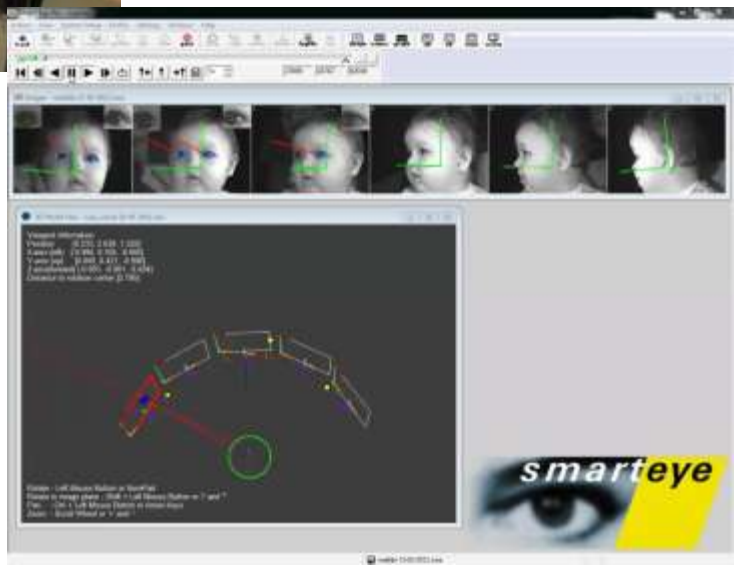
- This is a tool to **measure** specific abilities of the infants.
- The main aims are to know if there are changes in the motor development, to **measure outcome** and to **assess** the effectiveness of the **rehabilitation process**.
- It should be used with a **highly standardized protocol** and together with other **clinical measurements**.
- CareToy C is:
  - a highly equipped system,
  - installed in the hospital and
  - used only by the qualified rehabilitation staff.

CareToy C

- The fundamental building modules of the CareToy C are:
  - five screens;
  - eye tracker;
  - infant-seat;
  - sensorized toys

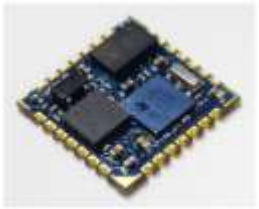


CareToy C



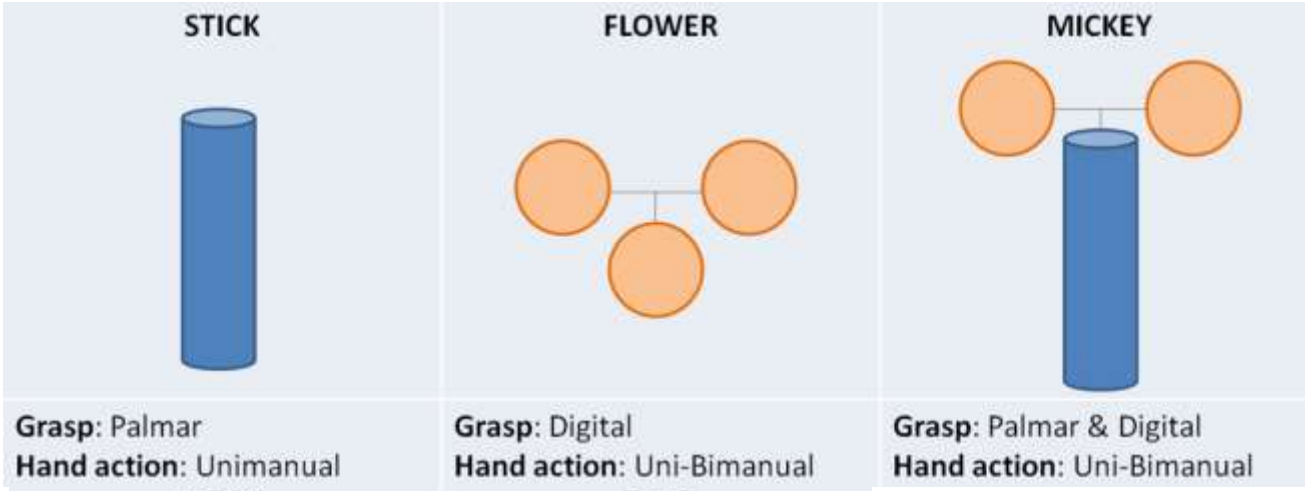
Sensorized toys

- Based on the concept of affordance **a kit of 5 toys**, inspired to existing toys realized for infants, has been designed and developed.
- The toys have the same features and different shapes.
- The shapes have been carefully chosen in order to have a clear affordance and encourage different manipulation approaches.
- Toys hardware contains (same electronic board):
  - 3 different types of sensors:
    - silicon piezoresistive pressure sensors.
    - Inertial sensors: INEMO-M1 from ST Microelectronics
    - force sensors: FSR by Interlink.
  - feedback:
    - Multicolour LEDs for light feedback on flexible Kapton circuit.
    - Piezo-speakers for sound feedback: so that the rehabilitation staff can modify the volume and the type of sound.



Toys shapes

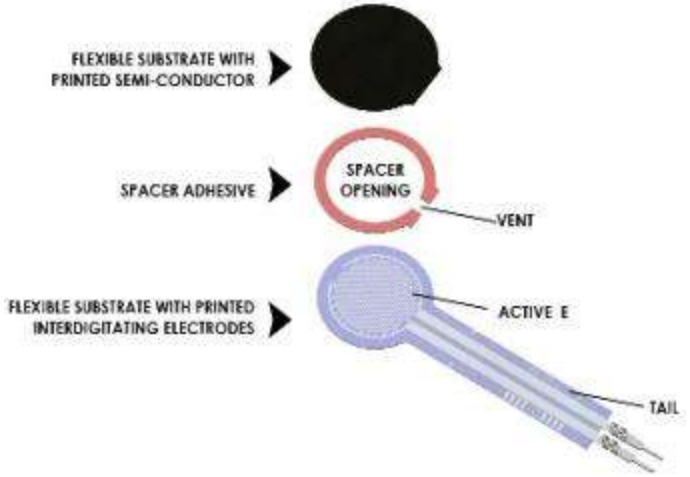
- 5 basic shapes has been chosen for the sensorized toys on the basis of the type of grasping (palmar or digital) and hand action (uni or bimanual) that we want to detect and monitor

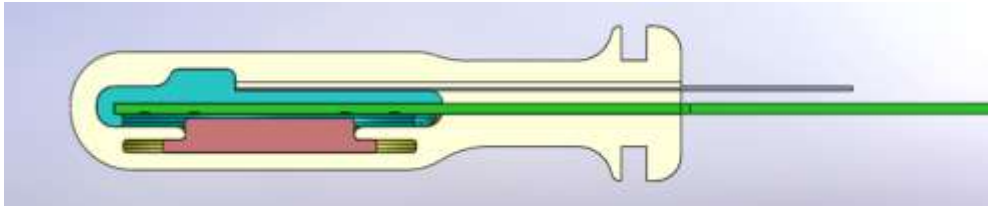


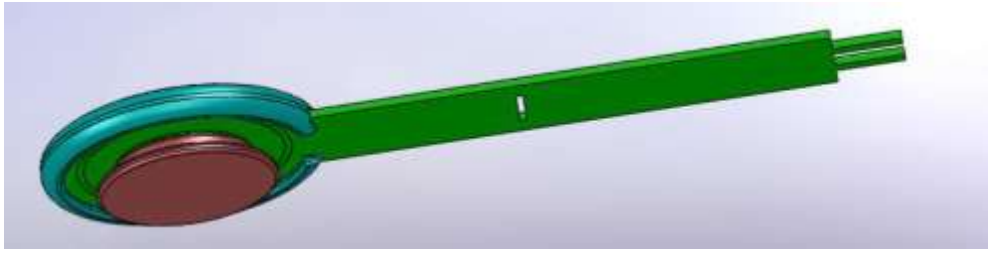
- Each sensorized toy is mainly composed of:
  - a soft part (made in elastomers) with embedded pressure and/or force sensors and lights;
  - a rigid case (made in epoxy resin) containing the electronic unit and the buzzer.

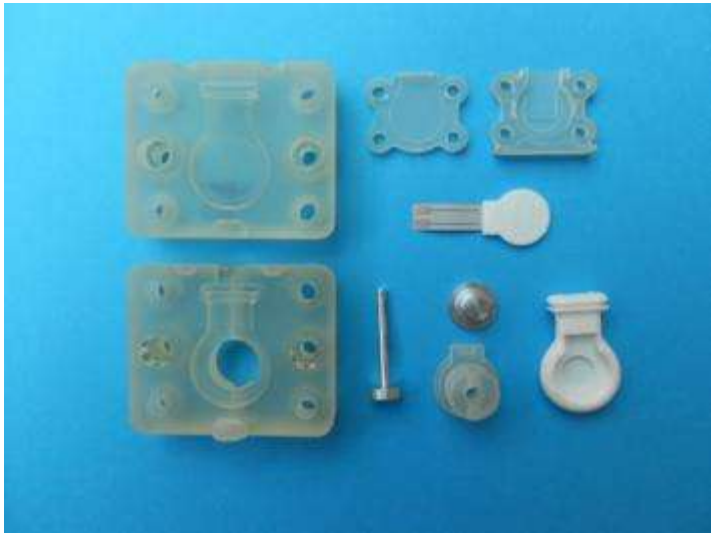
FRS

- FSR were embedded into a system designed in order to provide the acquisition of only the normal contribution of the applied force.

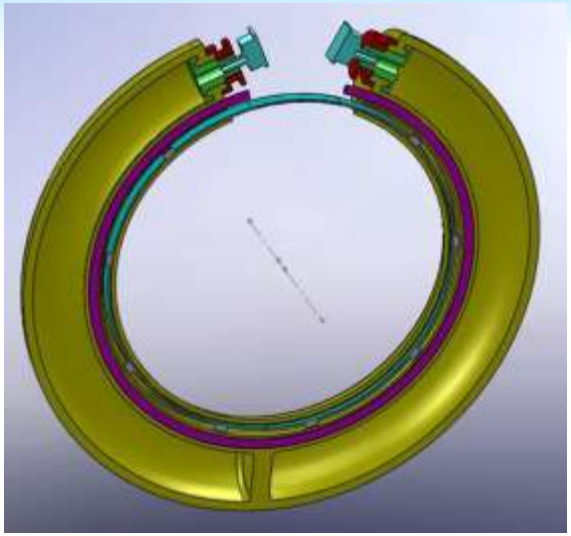


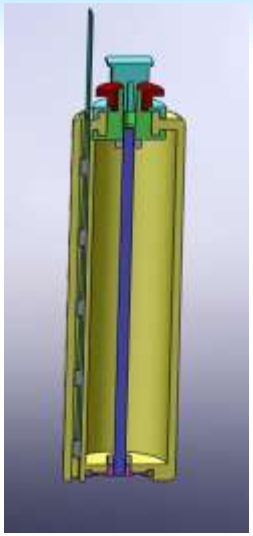






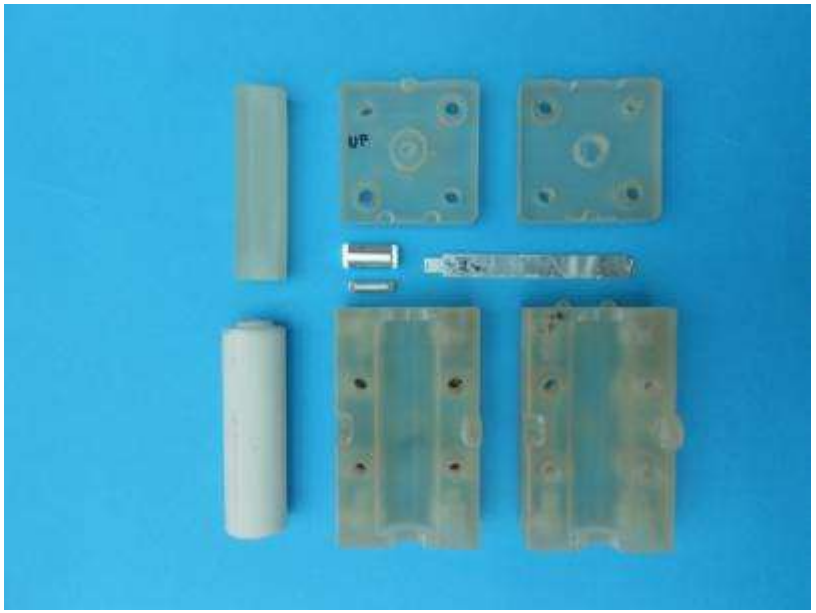
Pressure sensors



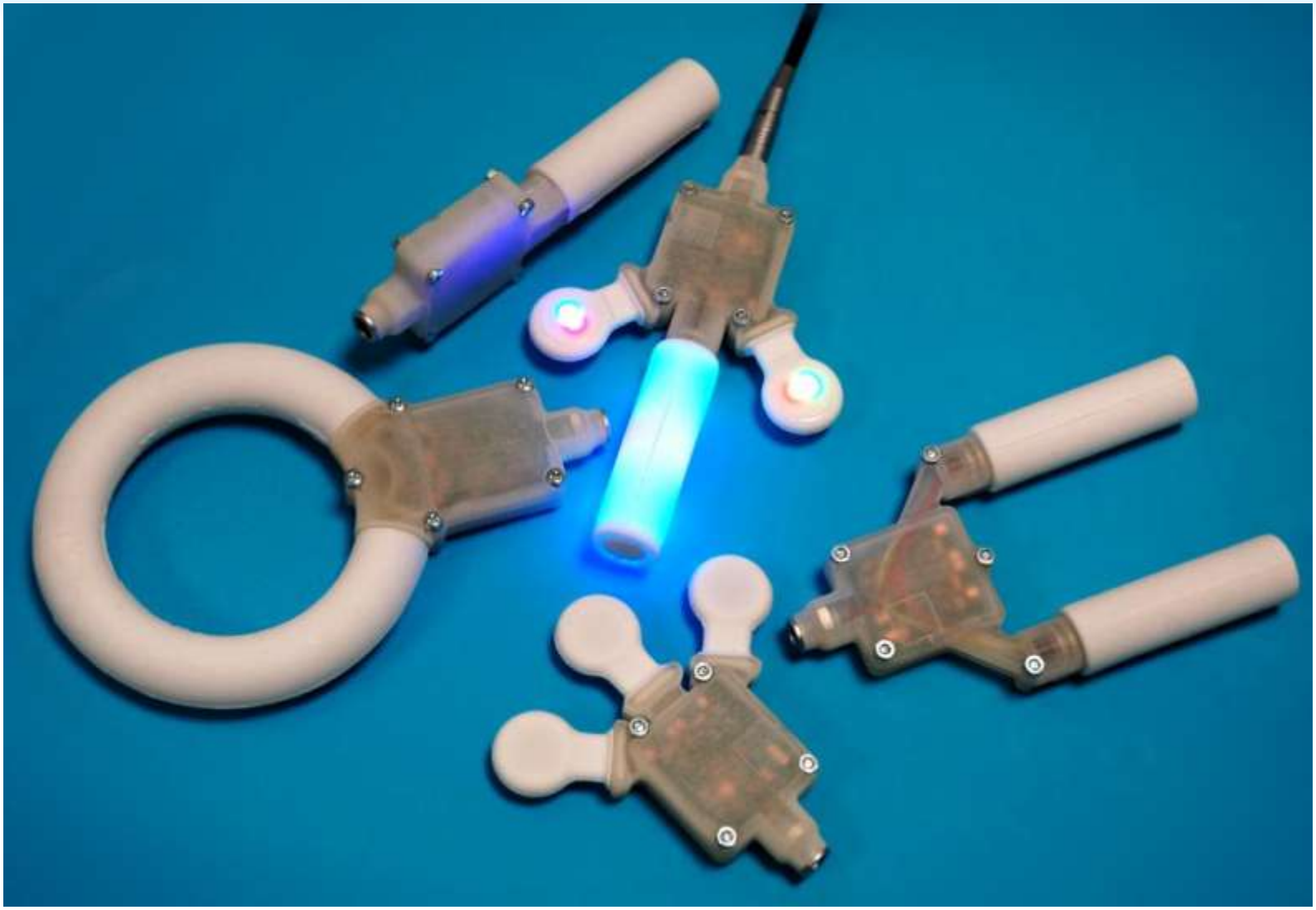


coupled to a soft air-filled chamber

- a toroid shape (for Ring toy)
- a cylinder shape (for Stick, Mickey and U-toy)



Kit of sensorized toys



Sensorized mat

Technology

• The mat will be composed of an array of optoelectronic sensors

• Dimension of sensor of about 13x13 mm^2

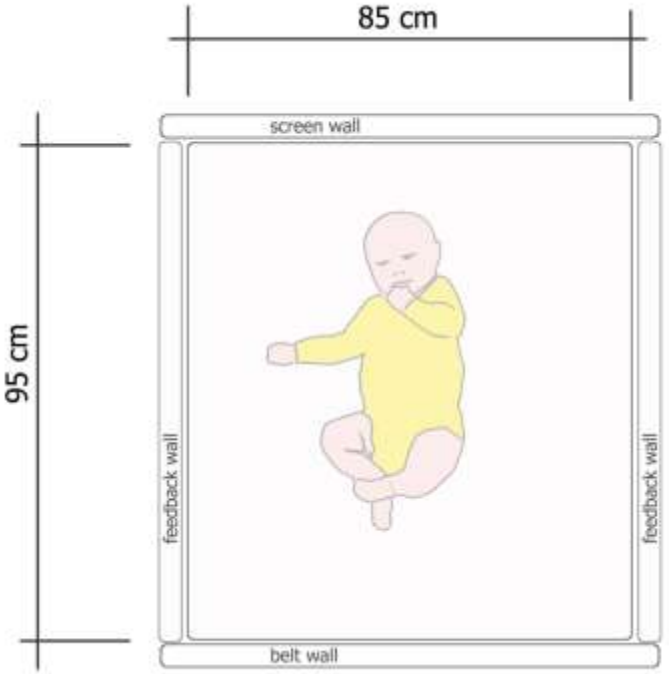
• Pressure range of about 2-10 kPa

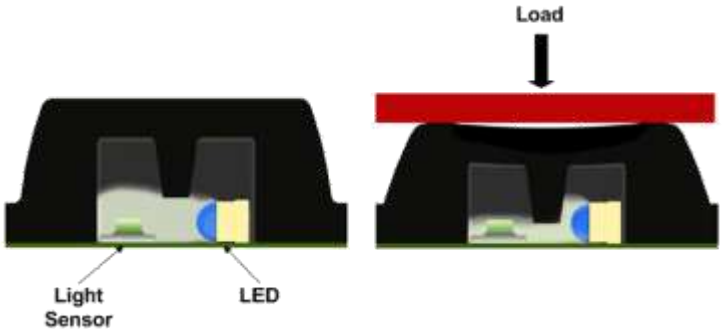
• Accuracy in the range of 2-5% of Full Scale Input;

• Dynamic behavior: time required for the pressure measurement is about 0.01 s

• Analogical output (voltage)

• Analogue signal does not need amplification

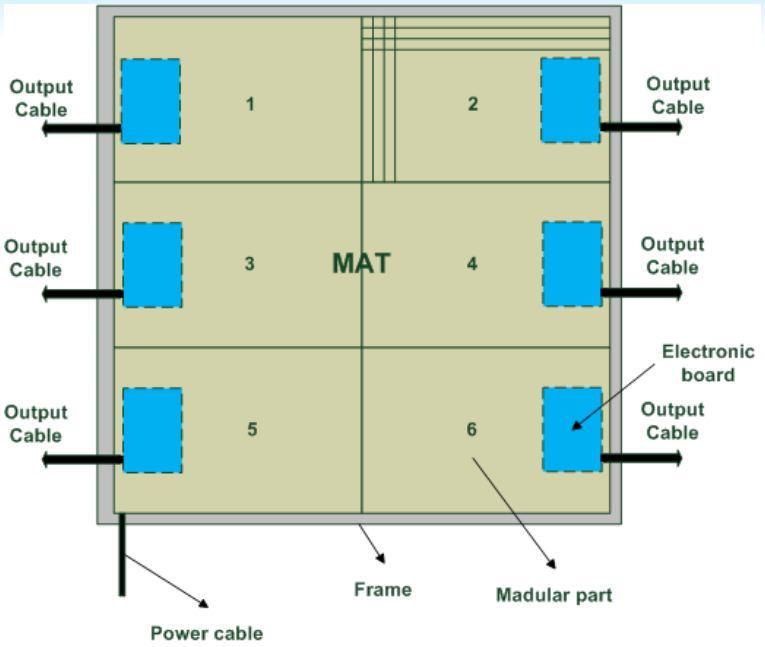


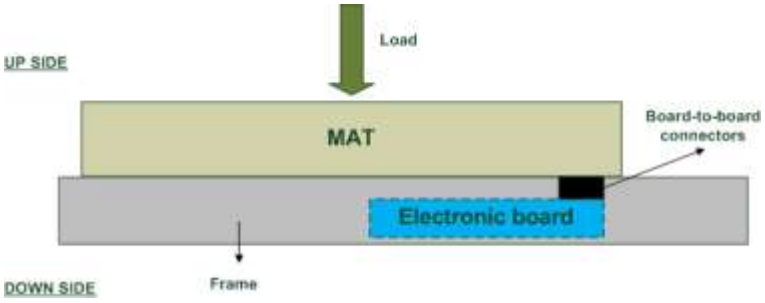


Mat architecture

Characteristics of mat

- Mat covers entirely the required area to be sensed, i.e., **~90x90 cm²**
- Spatial resolution: **13 mm²**
- Number of sensors: **4608**
- Modularity: **6 sub-modules,** mechanically fixed to a frame
- Sub-module electronics board is integrated into the retaining structure
- Each mat module is building block of all CareToy system sensorized mats
- Sensorized mat has a changeable coloured layer, and is easy to clean (no sterilization needed)
- Each sub-module has its own electronic board for data acquisition and processing
- Data to transmit: **pressure sensor output signal**
- Transmission protocol: serial protocol (e.g. USB)

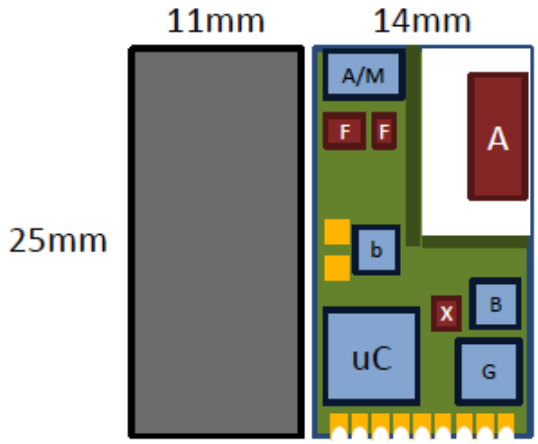




First prototype

Wearable sensors

- 3 wearable sensors (1 trunk, 2arms)
- Small system hosting the IMU section, the wireless connectivity and the battery management.
- The IMU integrates multiple ST`s sensors: a 6-axis geomagnetic module, a 3-axis gyroscope, an ARM® CortexTM M3 32bit MCU with embedded wireless transceiver (STM32W108), a power management unit for rechargeable battery.
- It combines accelerometers, gyroscopes and magnetometers to provide reliable drift-free 3D orientation estimation (Roll, Pitch and Yaw, Quaternions, Rotation Matrix), through a wireless radio.



- Li-Ion battery for the power supply unit
- static accuracy (roll/pitch) < 1deg
- static accuracy (heading) < 1.5 deg
- dynamic accuracy 2 deg RMS.

Scenario #1: feedback walls

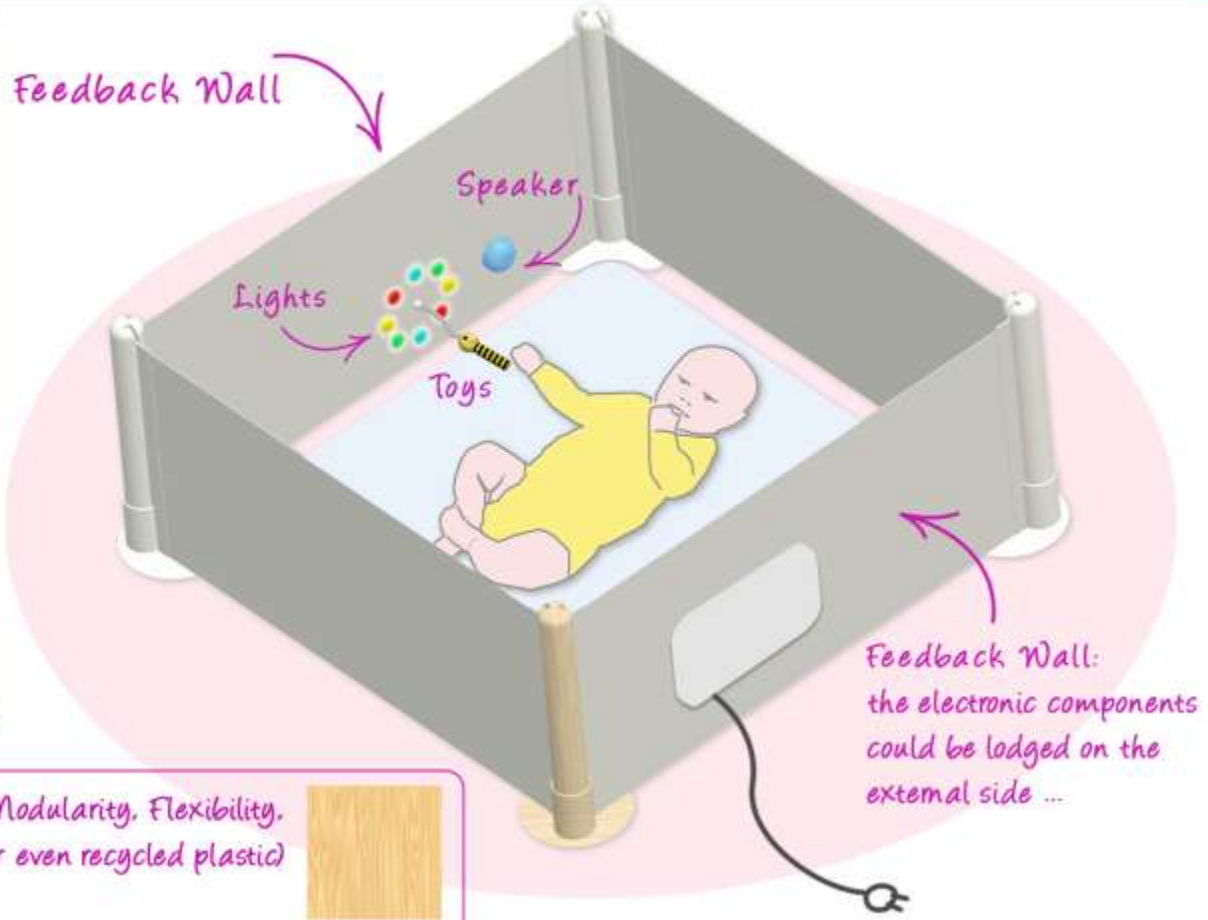
SCENARIO A

Walls material : e.g. foam rubber

with washable and easy
to change textile cover, like :

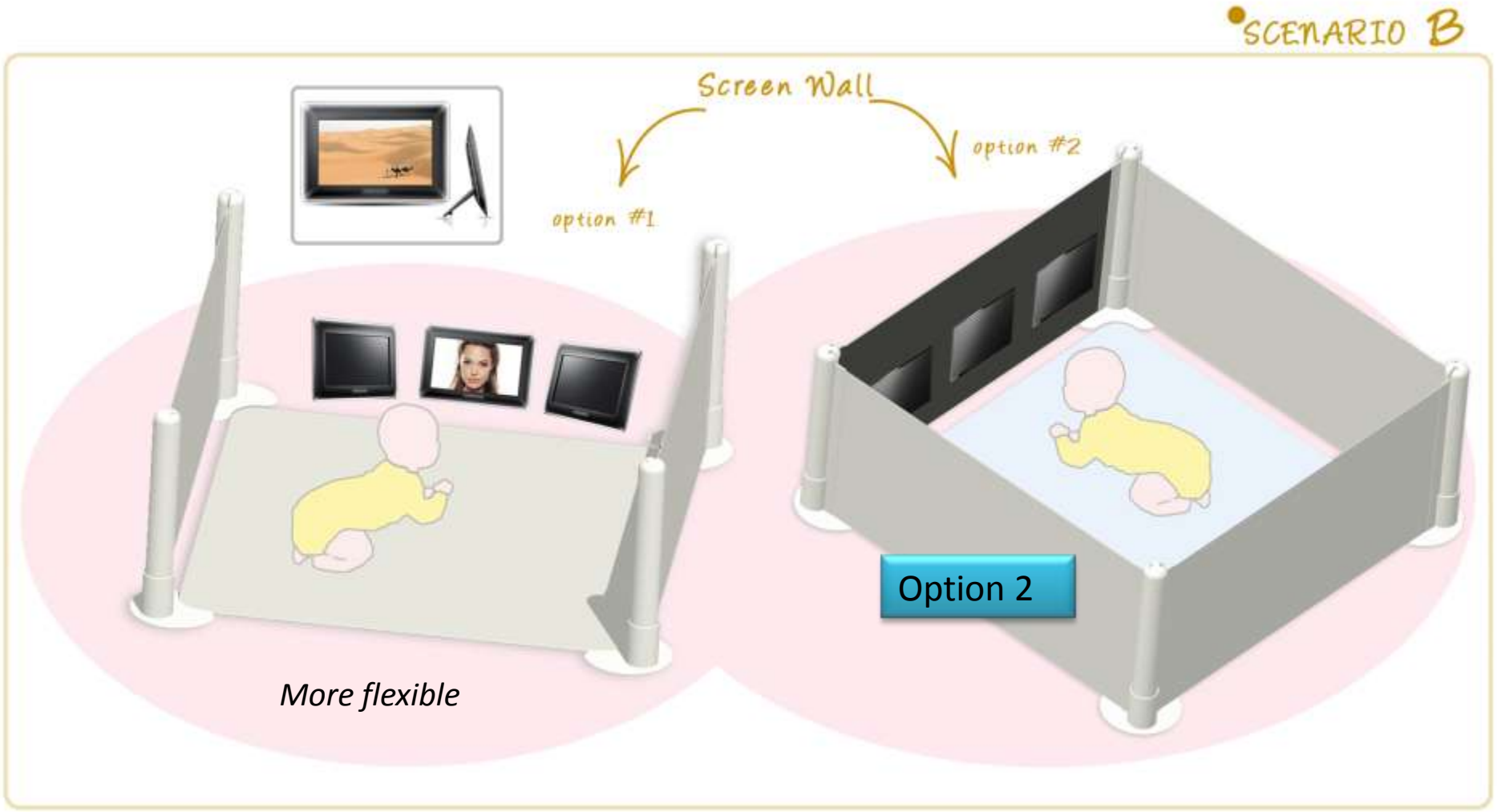
- neutral colours
- natural textiles
e.g. cotton, linen etc.

- colour contrast background

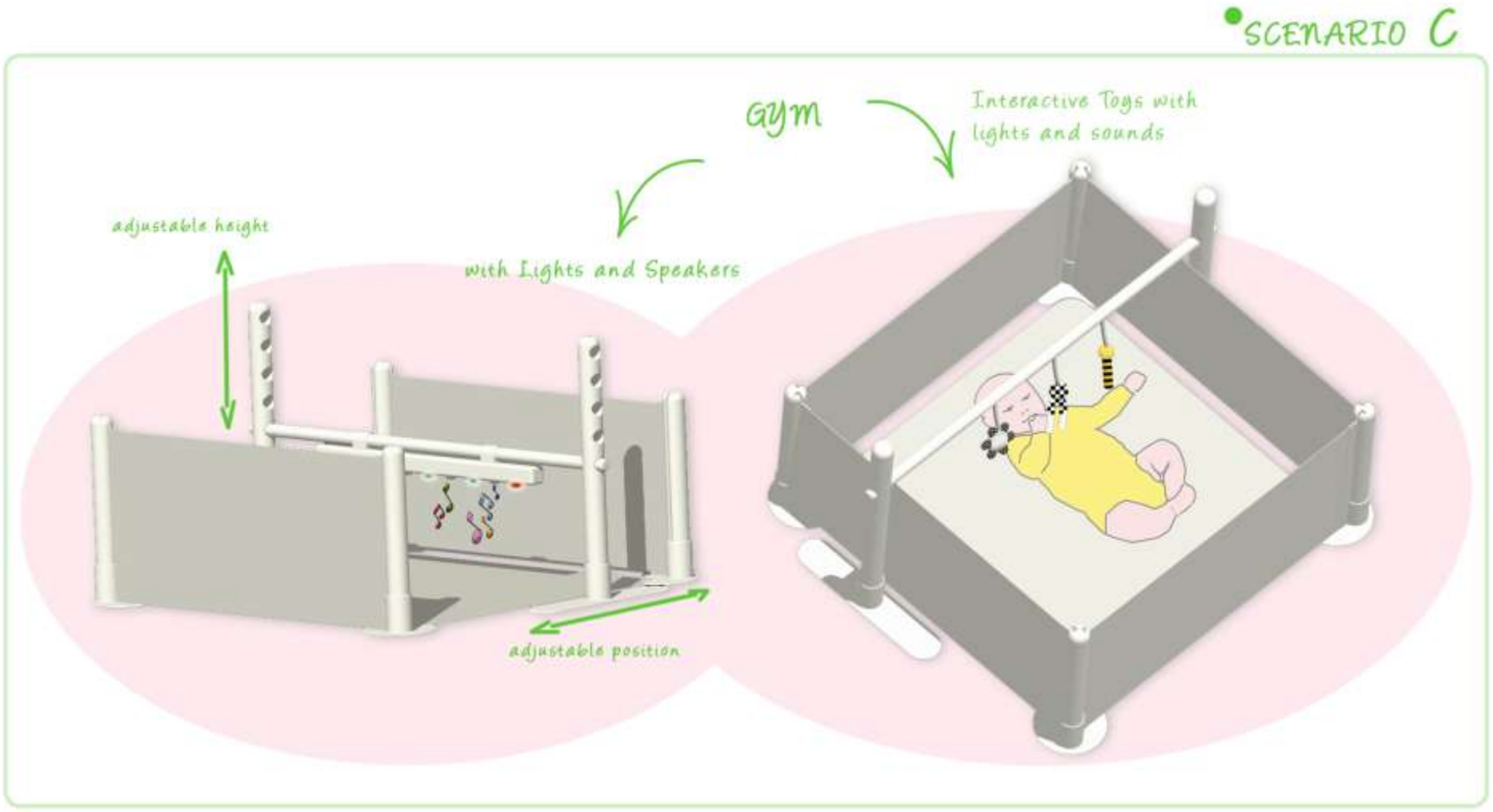


Walls and Gym Structure : Modularity, Flexibility,
warm materials e.g. wood and plastic (or even recycled plastic)

Scenario #2: Screen Wall

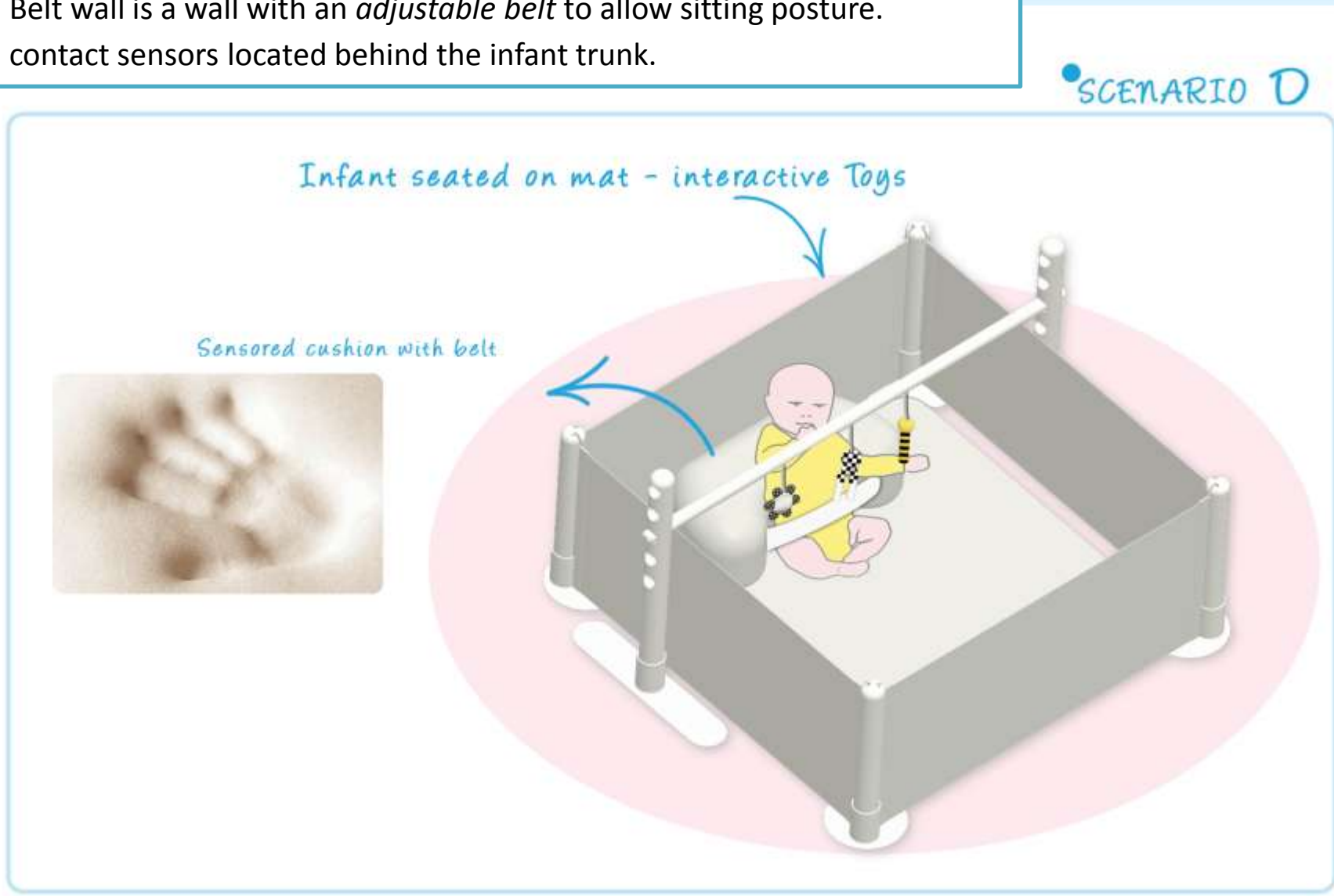


Scenario #3: Gym



Scenario #4: belt wall

- Belt wall is a wall with an *adjustable belt* to allow sitting posture.
- contact sensors located behind the infant trunk.



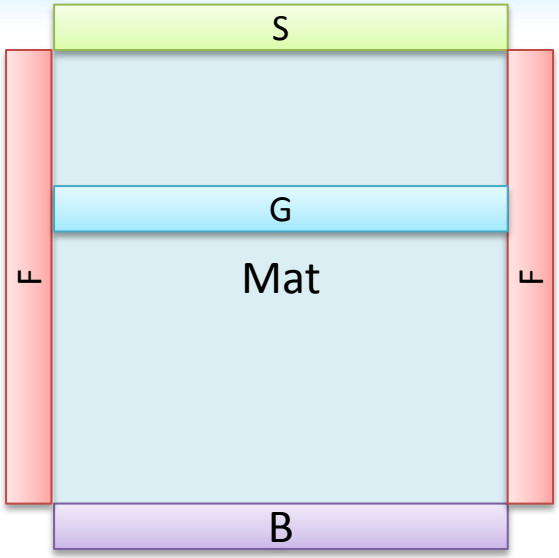
Interactive walls

Feedback wall (F)

Screen wall (S)

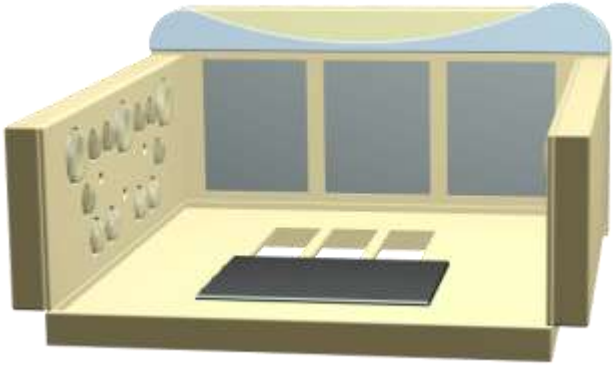
Belt wall (B)

Gym (G)

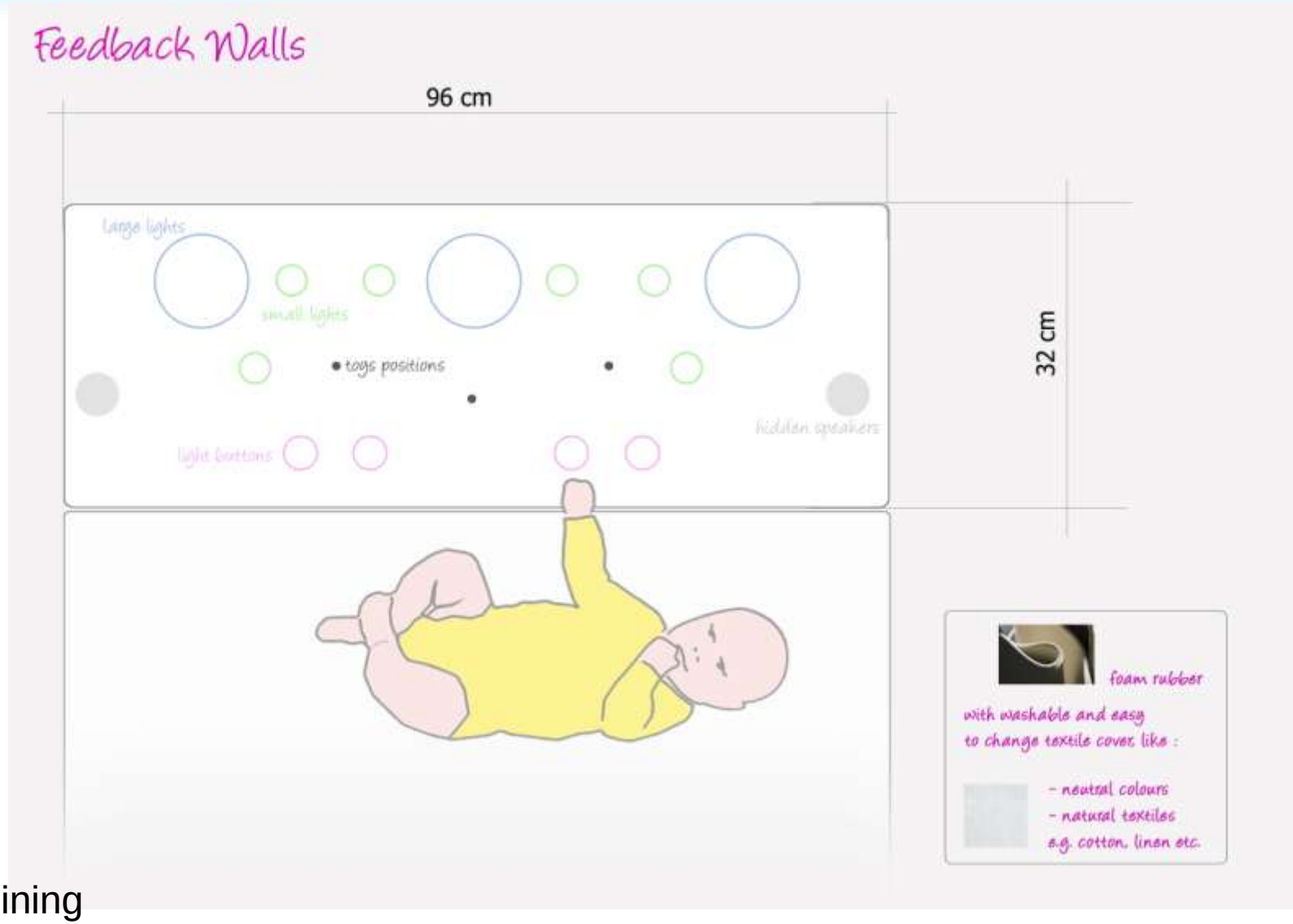


- **feedback** walls and the **screen** wall are fixed for all the scenarios
- the **belt** wall and the **gym** can be add according to the training session.

- Size: 90 cm x 40 cm.
- These walls complete the system and can provide audio-visual stimuli.
- Attractive because they provide the feedbacks for the infants in order to stimulate them.



Feedback walls



reclining

Lights (I)

Specifications:

- Many spots lights in the wall
- Low power dissipation
- Multicolor lights
- Flexible control interface

→ Low temperature bulbs

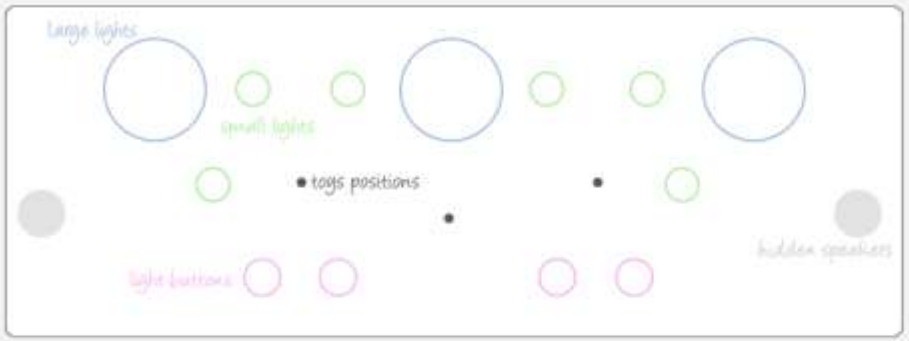
Solution

↓

integrate leds in to the walls: Led strip

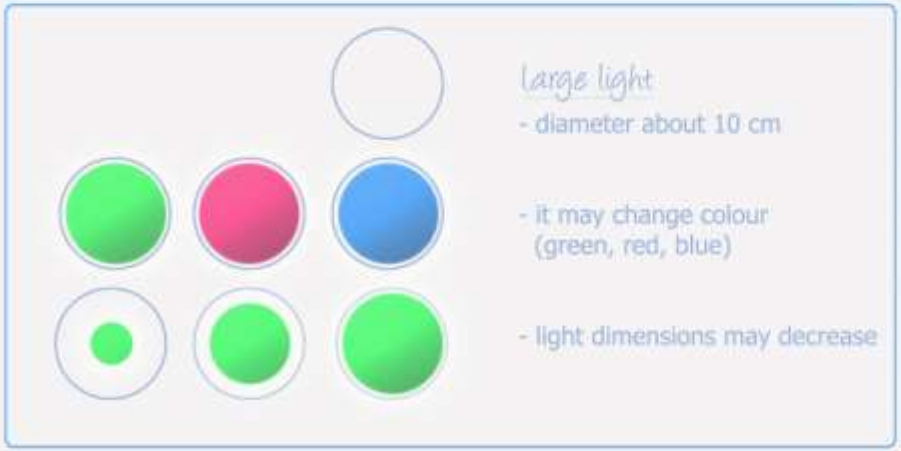
Lights (II)

Feedback Walls



ligth button

- diameter about 6 cm
- one colour
- when switched on it shows a funny face



large light

- diameter about 10 cm
- it may change colour (green, red, blue)
- light dimensions may decrease

small lights

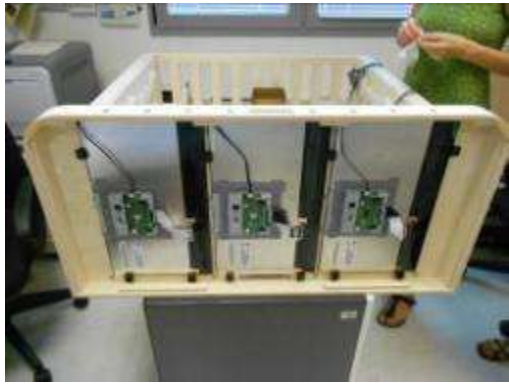
- diameter about 5 cm
- it may change colour (green, red, blue)

Light buttons

- Inspired to buddy buttons (commercially available)
- Different internal stencils
- Lights inside

Screen wall

- The **frontal** wall is provided by screens that can show moving pictures (animations) with and without sounds that switch on and off.
- **3screens** are embedded into the structure and a transparent Plexiglas cover has been placed in front of the screen as protection for the infant.
- Also in this case the wall is made by **natural wood** and is covered with a removable and washable padding.

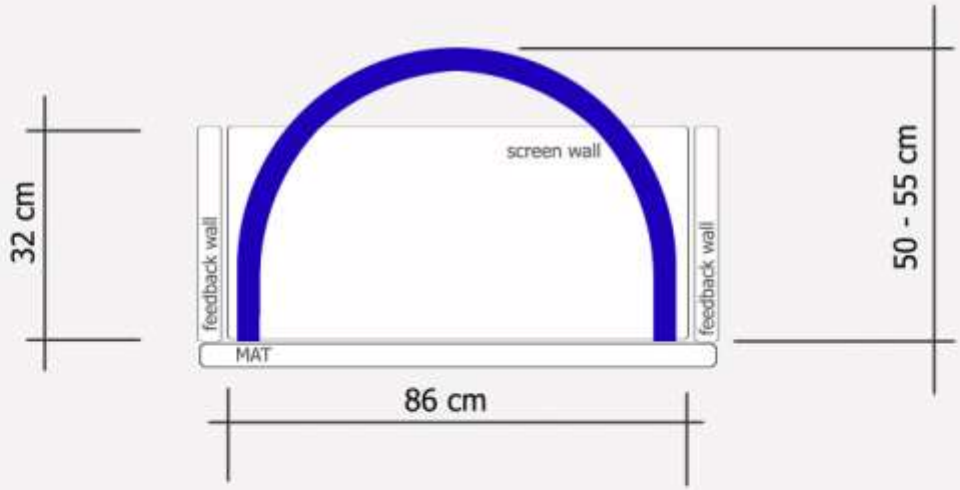


Belt wall

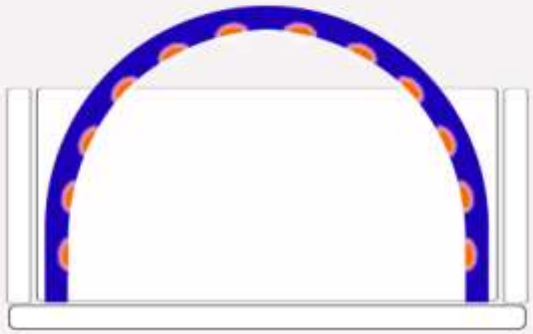
- The fourth wall is the belt wall composed of wood structure, inspired by **bed edge** for children with an adjustable **pillow** in order to allow sitting posture.
- This soft pillow is equipped with a **switch** (for detecting if the infant is against the wall or he/she moves forward) and a belt for allowing the infant to sit by laying his/her back against the wall.

Arched gym (I)

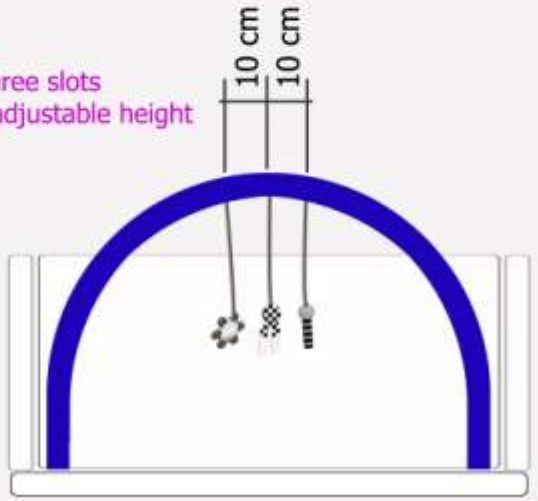
ARCH



N°12 orange lights: - diameter about 5-6 cm
- distance between lights: 5-6 cm
- one colour



Toys: - three slots
- adjustable height

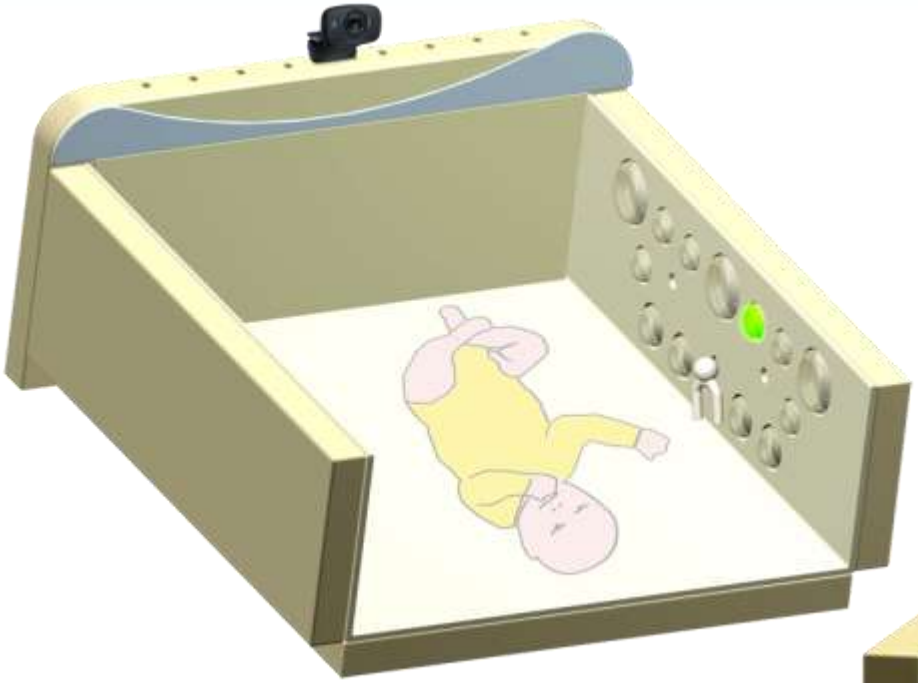


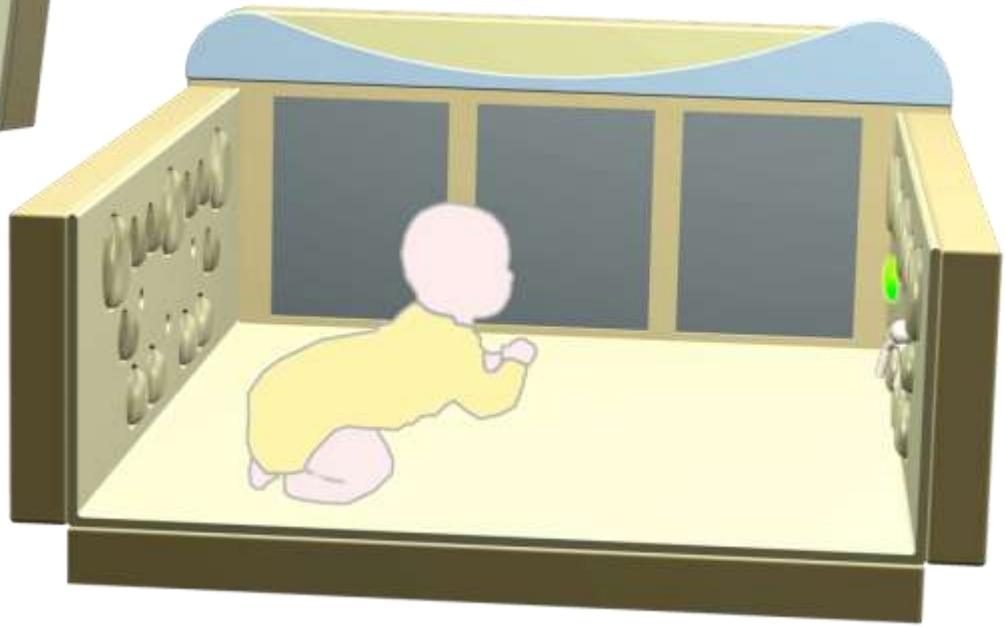
Arched gym (II)

System integration (I)

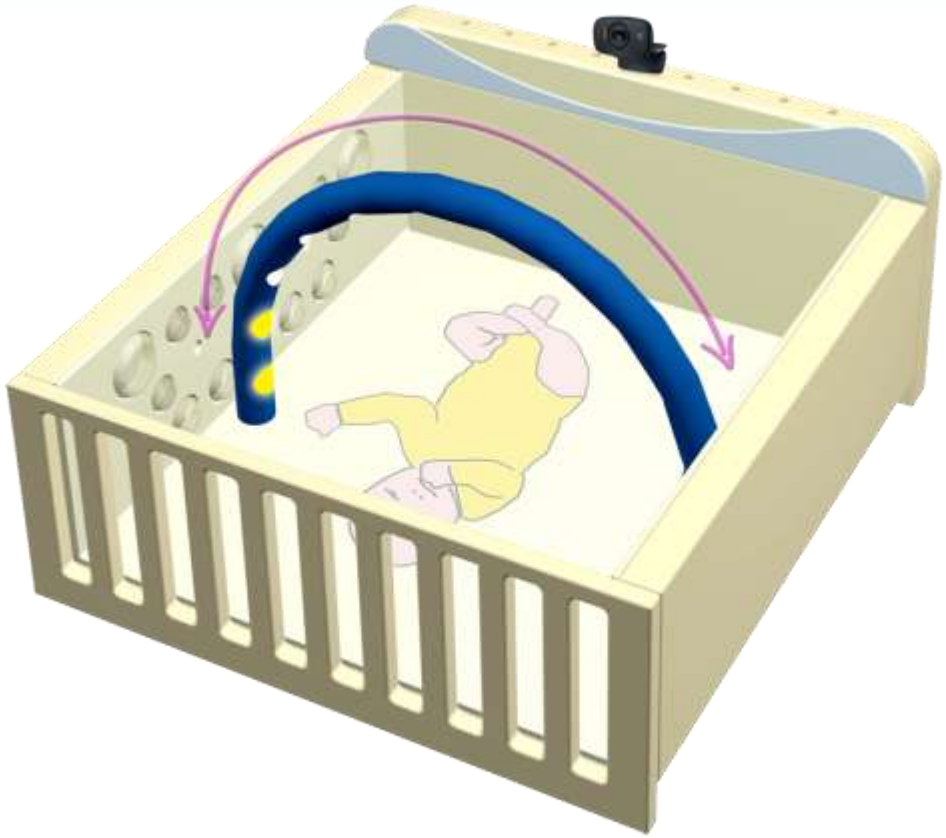
System integration (II)

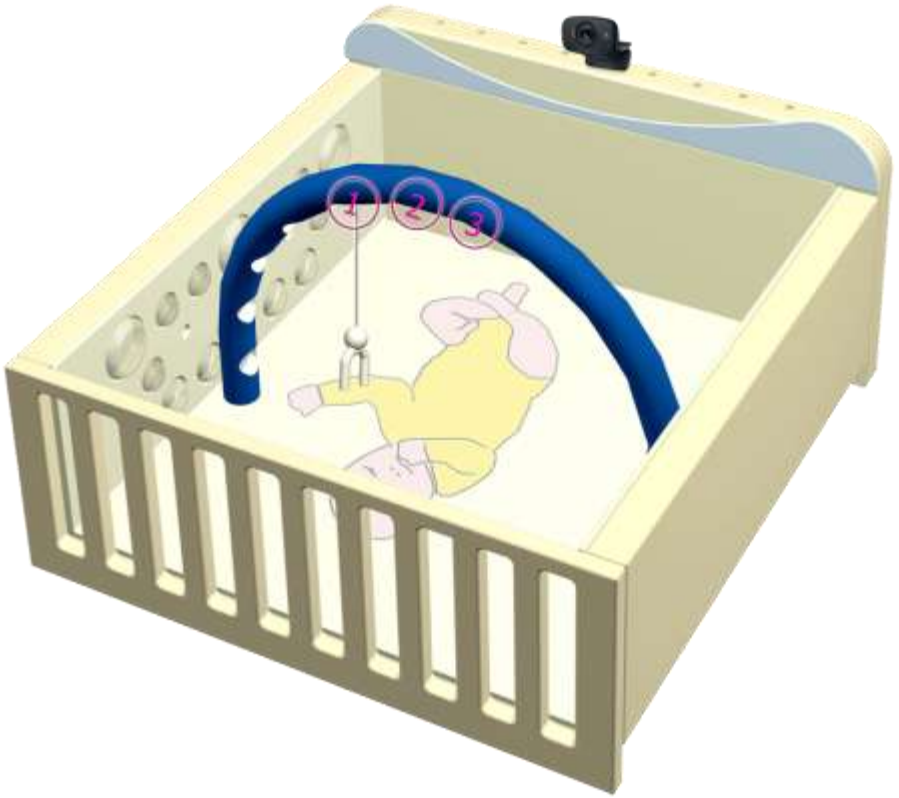
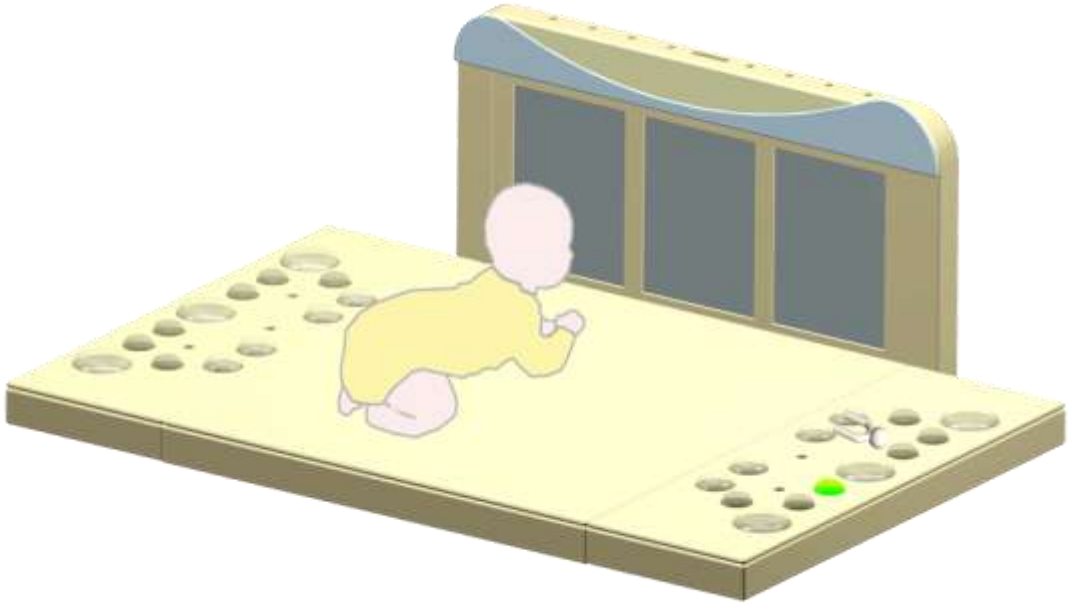
Examples of experimental scenarios (I)





Examples of experimental scenarios (II)





Examples of experimental scenarios (III)