Applications of Multimedia Technology to study of the ordinal competencies of scholars from 3 to 7 years old

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Contents

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Starting point 1

The start

The results from the research studies developped in the Department of Didactic of Mathematics about:

- Inductive and ordinal thought (Ortiz, 1997), (Fernández, 2001).
- Natural relative numbers (González, 1998).

The goal

To continue the on going researches on prenumerical and preinductive level from three to seven years old.

Starting point 2

We have a problem:

Traditional research methodologies in Mathematics Education (interviews, written questionnaires, objetive test, observation, . . .) *with young children* have disadvantages:

- Undesired interactions between subject and researcher.
- Low motivation and implication of the subjects.
- Difficulties to obtain the information.
- Limited functionality and limited information recovery.
- Higher subjectivity.

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Starting point 3

A solution? Conjecture 1:

The multimedia technology allows us to configure an scenario and a research methodology adapted to the ages and psychological characteristics of subjects.

Some advantages

A multimedia methodology have *a priori* advantages:

- Better motivation and implication of the subject.
- Better concentration of the subjects on the tasks.
- Minimal interaction between subject and researcher.
- Automatic and objetive record of information.
- We can obtain a bigger amount of information easily.

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The problem

The goal + conjecture 1 ⟶ new approach:

To configure an scenario and a research multimedia methodology, according to our evolutive model, and to study the ordinal competences from 3 to 7 years old.

What is known? Wich are our basis?

The ordinal skills and competences

- Epistemology of natural numbers and ordinal structures.
- Orderings and quantity, number and measure concepts.
- Orderings and the natural number from the cognitive point of view.
- The research studies that are being in the Department of Mathematics Education.

The multimedia technology

- Multi–modal functioning.
- Multimedia learning.
- Human–computer interaction.

The ordinal skills and . . .

Epistemology

- Insufficience of Cardinal concept: the sets $\mathbb{N}$, $\mathbb{Z}$, and $\mathbb{Q}$ are indistiguishable from a cardinal point of view (Hrbacek and Jech, 1999).
- Relevance in orderings: they are distinguisable by linear orderings.
- Natural numbers are a synthesis of cardinal, ordinal and inductive components.
- Compatibility with Piaget's theory.

Quantity, number and measures.

- Metrics concepts are generated in a synthesis between comparative and numbers concepts.
- Numerical sets and the state ordered series of quantities are isomorphic systems, are substained mutually and, possibly, also they are coherent at the level of the construction by the individual subjects (González, 1998).
- Orderings and comparative concepts are closely linked and are both on the basis of numerics and metrics concepts, so its logical to supose that those individual development will directly influence the individual evolution of these.

The cognitive point of view

- The cognitive researchs do emphasize the operational and heuristic aspects of natural number, taking his cardinal aspect as a reference, regardless the integration of his inductive properties with his cardinal and ordinal aspects.
- Few experiments have studied the ordering of numbers in young children.
- Orderings concepts are among the slowest to be put in place in the children's mind.
- Dehaene's hypothesis: the adult number line and existence of a deep relation between number and space (Dehaene, 1997).

The research in the Department

- Inductive numerical thought (Ortiz, 1997).
- Logical ordinal relations in the numerical sequence (Fernández, 2001).
- Relative natural number (Ortiz, 1997).
- Obtaining of evolutionary models of inductive and ordinal thought, (Ortiz, Fernández, Op. cit.).

Evolutive model of ordinal competences

Basing on the previous studies we do the following conjecture:

Conjecture 2: The evolutive model

The ordinal competences of children of 3–7 years old will develop with age according to the following levels:

- ***Linear infralogic ordering***: Competence to ordering the points in a line. Ordinal concepts: "before that", "after that", "preceding", "next", "forwards", "backward".
- ***Labeling***: Competence to assign a simbol, sign, word or concept to every element included in a series.
- ***Ordering on continuous quantities***: Competence to ordering longitudinal objets. Ordinal concepts: "more than", "less than", "greater than".
- ***Ordering on discrete quantities***: Competence to ordering discrete objets. Ordinal concepts: "more than", "less than", "greater than". The aim is to detect when individuals begin to spontaneously use the counting as an strategy in the assignment of ordinal positions and when they distinguish the discrete from the continuous quantities in the arrangements.

Multimedia scenaries and multi–modal functioning

Visual and Spatial Mode ✦ Layout and positioning. ✦ Angle and perspective. ✦ Graphics and their relationship to the text and sounds. ✦ Shape and size. ✦ Colour. ✦ Sequencing of items.	**Linguistic Mode** ✦ Absence or presence of words. ✦ Choice and use of words. ✦ Presentation of text. ✦ Symbols and icons.
Audio Mode ✦ Music. ✦ Sound. ✦ Silence. ✦ Dialogue and voice–over. ✦ Expression, mood, tone.	**Gestural and Movement Mode** ✦ Movement direction and speed. ✦ Dynamic interaction, cause and effect. ✦ Dramatic effects. ✦ Facial expression and body language.

In our study we consider,

Multimedia scenaries:
virtuals environments created and executed by a computer that includes all or some of the multimodal components:
visual and spatial, linguistic, audio, gestural and movement.
See figure (Way, 2003).

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Learning & human–computer interaction. –11–

Multimedia learning.

- We consider both approaches (Mayer, 2001): learner–centered and technology–centered.
- The first, to build playfull tasks, in a multimedia scenario, adapted to the children's cognitive and affective characteristics.
- The second, to record the information of the subject–computer interaction, with objetivity and minimal interaction subject–researcher.
- We have taken into account the *principles of multimedia learning* as *principles of multimedia design* (Mayer, 2001; Mayer and Al., 2005).

Human–computer interaction.

- Current computer systems are actually *cognitive devices* and also *simulation devices* (Turkle, 1995).
- The contemporary computer systems perform two broad classes of functions: *epistemic functions* and *ontic functions* (Brey, 2005).
- *Epistemic functions*: the computer functions as a cognitive device that extends or supplements human cognitive functioning.
- *Ontic functions*: computers simulated environments and tools to engage these environments.
- We redefine and adapt these general functions to a useful way for our study.

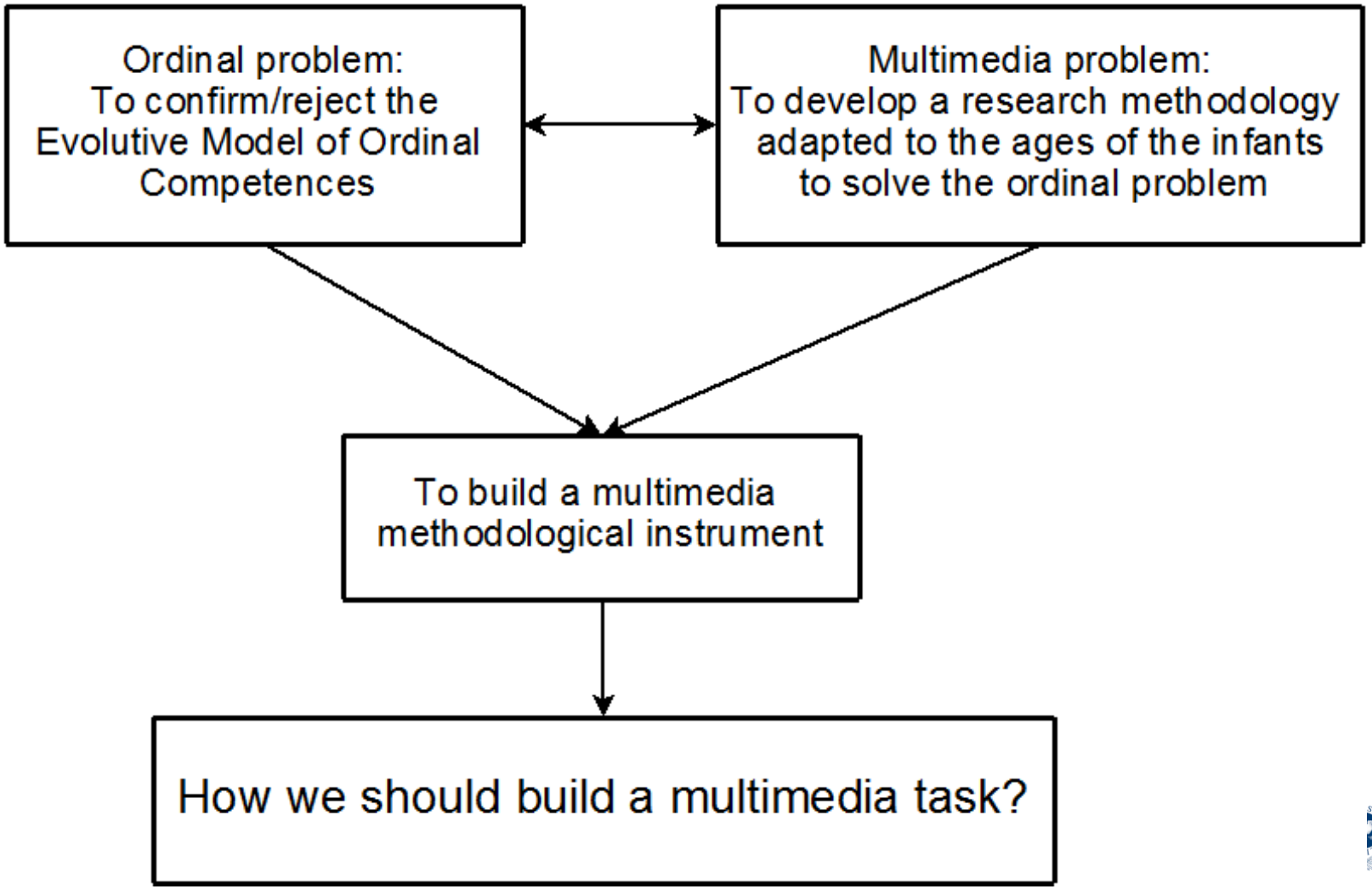
Epistemic, ontic and ontic–epistemic functions

In this study we redefine:

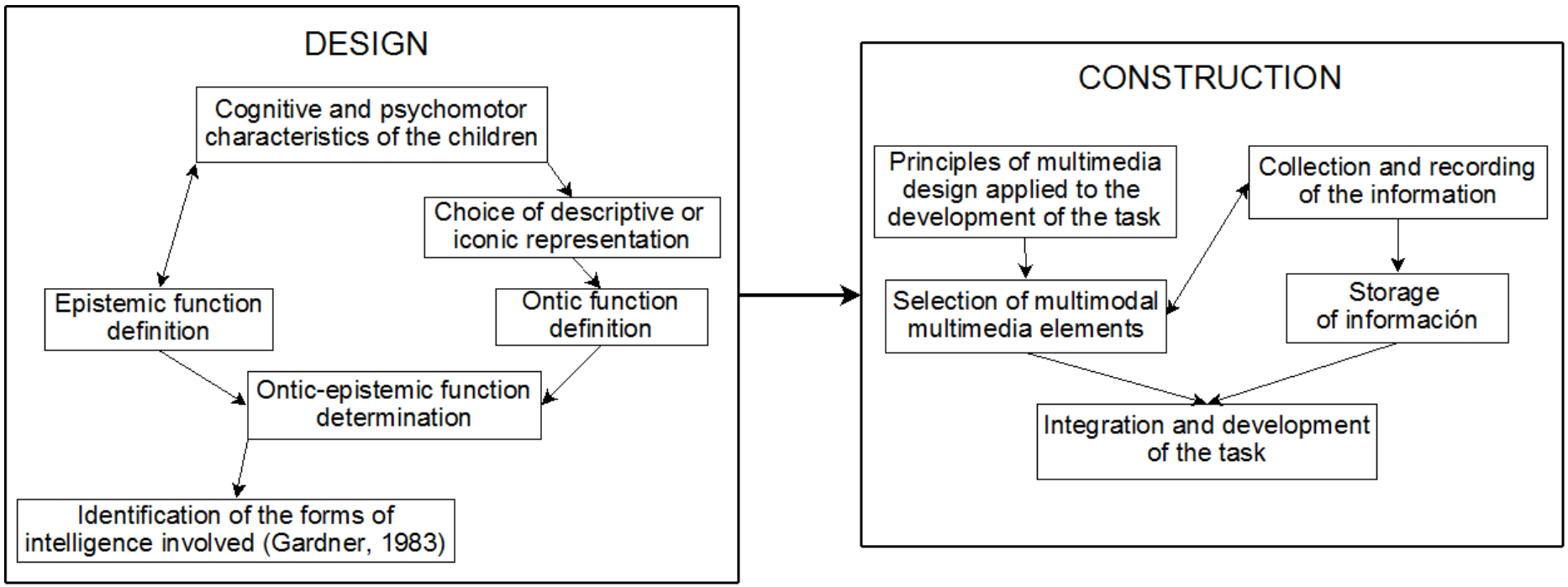
Functions:

- *Epistemics*: they define the *specific ordinal task* to be solved.
- *Ontics*: they stablish *interactive virtual environments* in wich task are performed.
- *Ontic–Epistemics*: as a combination of previous, they define the *precise virtual task* to be solved.

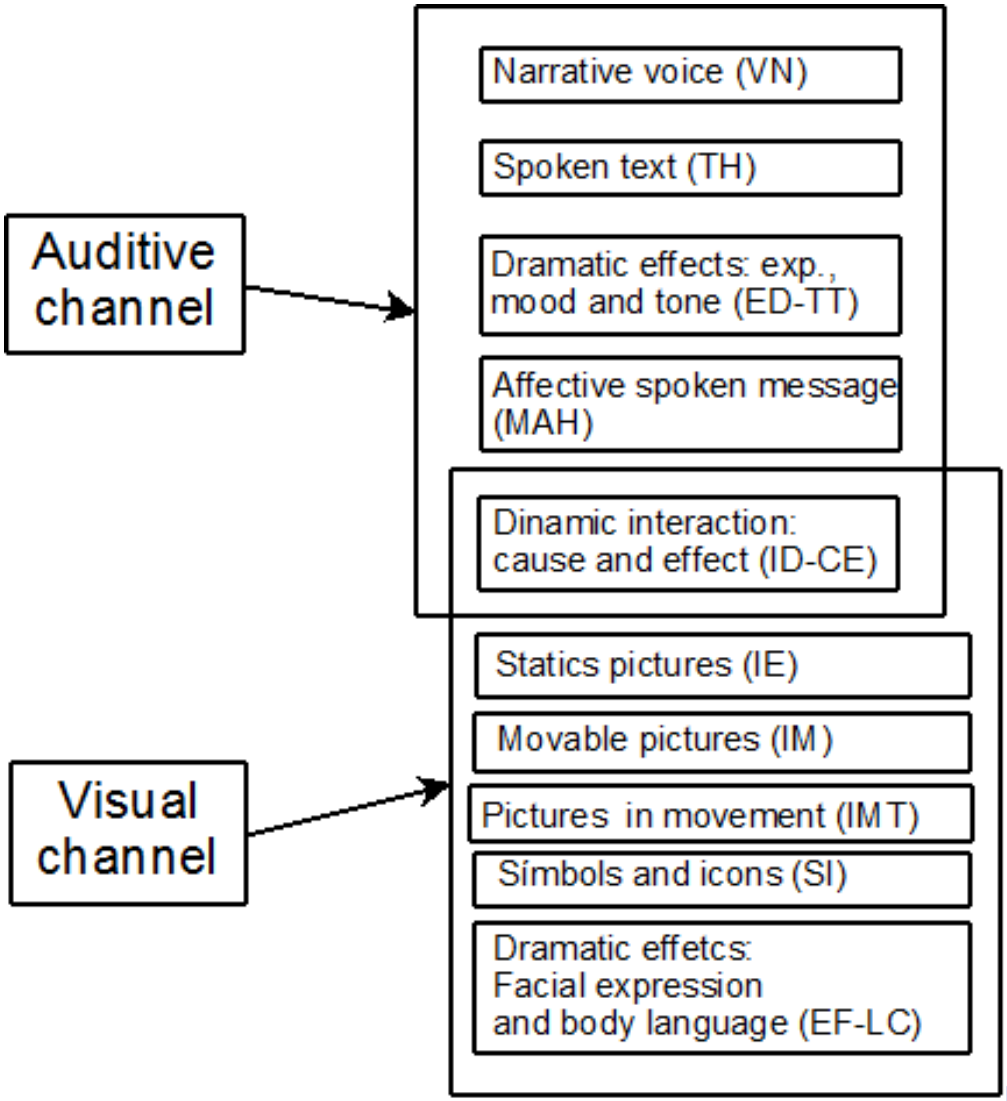
What do we do to confirm/reject the conjectures?



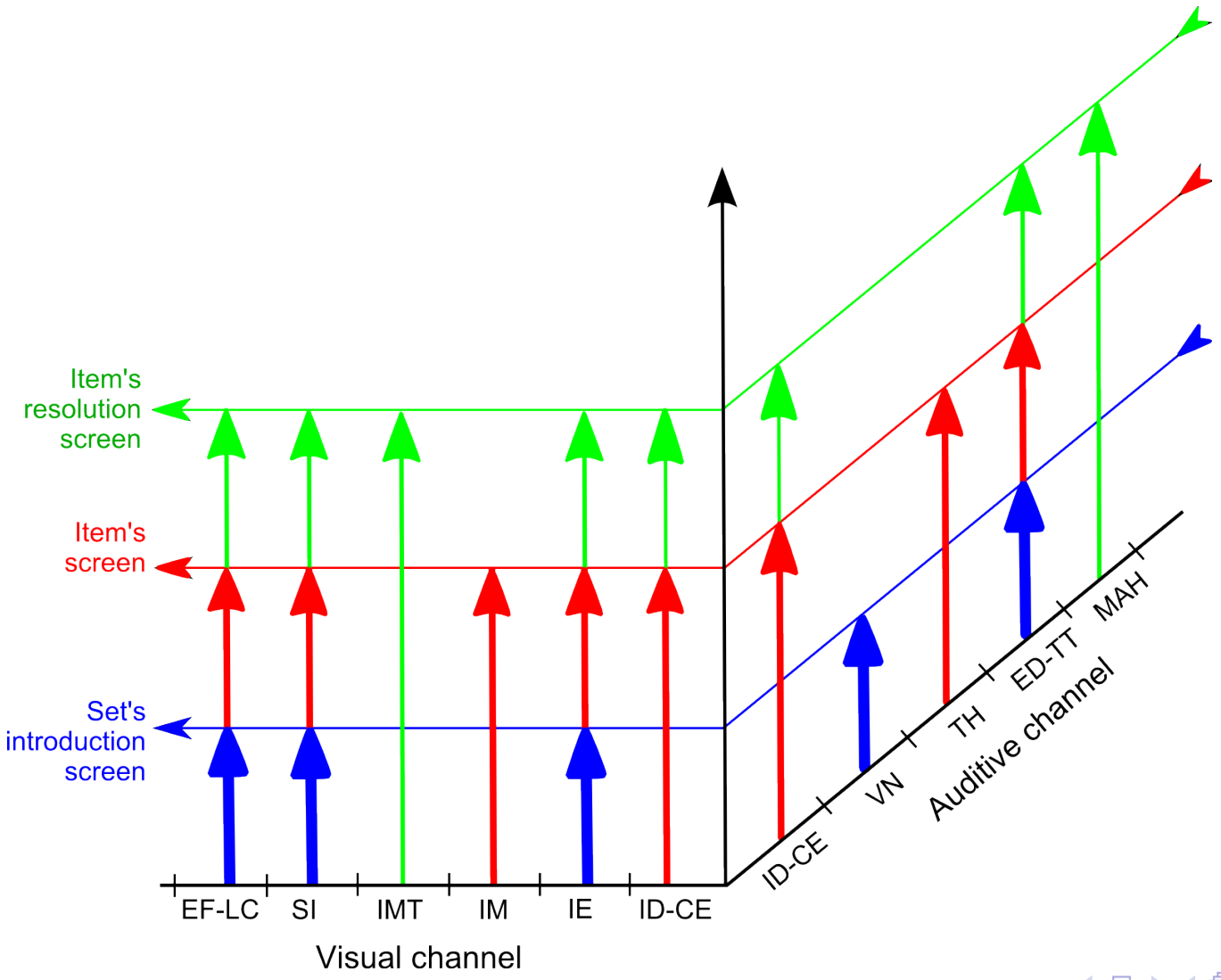
Process for a task



Multimodal elements by channels



Multimodal elements in the sets of tasks



The sets of tasks have been made with **Macromedia Director.**

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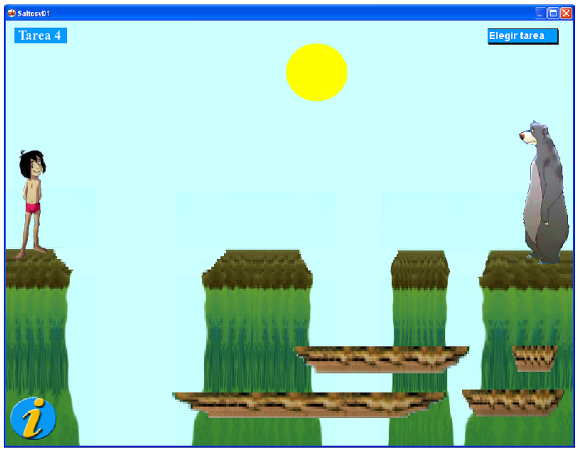
Technical sheet of a task

Tarea 4	
Audio $\Longrightarrow$	*"Mowgli quiere pasar junto a su amigo Baloo. Arrastra y coloca los troncos que necesita para conseguirlo".*
$\Downarrow$ **Función Onto–Epistémica** $\Uparrow$	
Interfaz $\Longrightarrow$	
Objetivo $\Longrightarrow$ $\Updownarrow$ **Función Epistémica**	Observar si el sujeto establece o no algún orden por tamaños, las estrategias seguidas y si discrimina o no el elemento sobrante, cuando le pedimos que coloque tres objetos lineales a elegir de entre cuatro, donde uno de ellos (el más largo) no se halla en correspondencia serial con ninguno de los huecos a cubrir.
Descripción:	En esta tarea se ha mantenido el orden decreciente en el tamaño de los huecos, por tanto la estrategia decreciente coincide con la estrategia de colocación izquierda–derecha; de nuevo, es de esperar que sea la más utilizada. Pretendemos, además, determinar si la edad del sujeto influye o no en la discriminación del elemento sobrante.

Cuadro 1: Ficha técnica 10. Cuarta tarea de orden con can-

Full study include four categories of tasks

According to the levels of our evolutionary model:

Sets of Tasks:

- *Linear ordering*: they are interactive games, the subject must identify, by clicking, the right path where are available several fruits, in accordance with certains serial patterns.
- *Labeling*: They are interactive games in which the subject must locate the positions of certain fruits concealed by the principal character, by means of cyclical alternations, in the rungs of a ladder doing click on them.
- *Ordering on continuous quantities*: The subject must drag and drop figures, that simulate logs, into the correct positions to help the main character to save the holes and join the secondary character, that is on the other side of the road.
- *Ordering on discrete quantities*. It consists of two subsets:
  - In the first, the subject must drag and drop several discrete amounts, from one to five fruits, in their correct positions that are at different sets of holes, placed on different trees. Fruits and holes are on numeric correspondence.
  - In the second, the child should drag and drop pieces, that simulate sets of two to six steps, to form a ladder that allows the main character to climb to reach the fruit, that is in an elevated position in the tree.

We have chosen some characters in the movie *The Jungle Book* to participate in the tasks, as motivators elements.

Linear ordering tasks

Audio: Each task has its own audio message.

They are six verbal task:

- **Task 1**: Make sure that the children know the scene and the actions to take in subsequent tasks.
- **Tasks 2 and 3**: Apply correctly the concepts before and after, respectively, to a topological or spatio-temporal serie.
- **Task 4 and 5**: Identify a complete serie of three (first-then-last) and four (first-after-after-last) linearly ordered elements.
- **Task 6**: Identify a complete serie of four elements, starting from intermediate positions (sequence: after-before).

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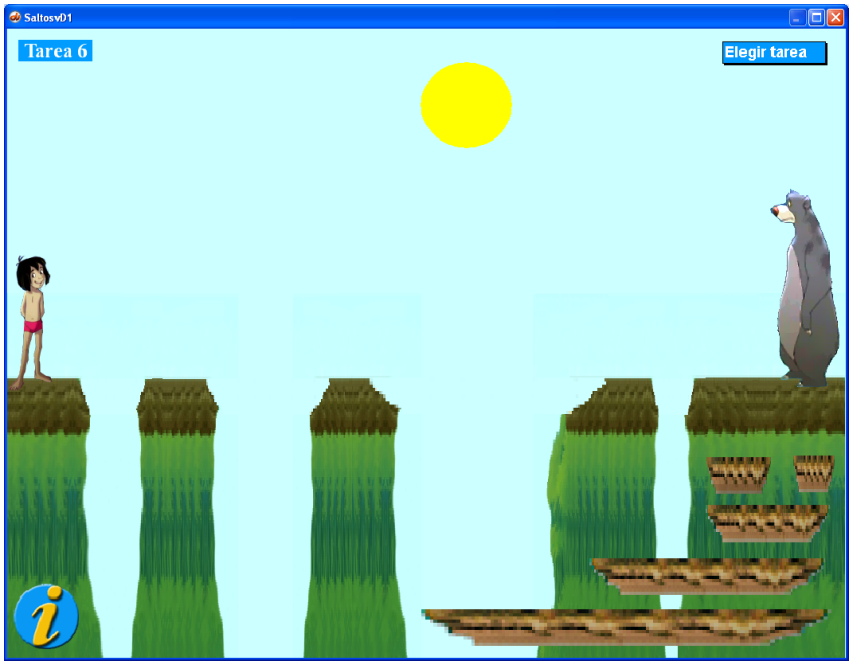
Ordering on continuous quantities



Audio: The audio message is common for all tasks, *"Mowgli want to meet with his friend Baloo. Drag and drop the logs you need"*.

They are six non–verbal tasks:

- **Task 1**: make sure that the children know the scene and the actions to take in subsequent tasks.
- **Tasks 2**: Ordering by size two linear objects and observe thr strategies used.
- **Task 3**: ordering by size two linear objects, to choose from three, when the shortest does not correspond to any of the holes to be filled.
- **Task 4**: ordering by size three linear objects, to choose between four, when the longest does not correspond to any of the holes to be filled.
- **Task 5 and 6**: ordering by size more than three linear objects when there is no kind of suggestion implicit in the order of placement in the holes.

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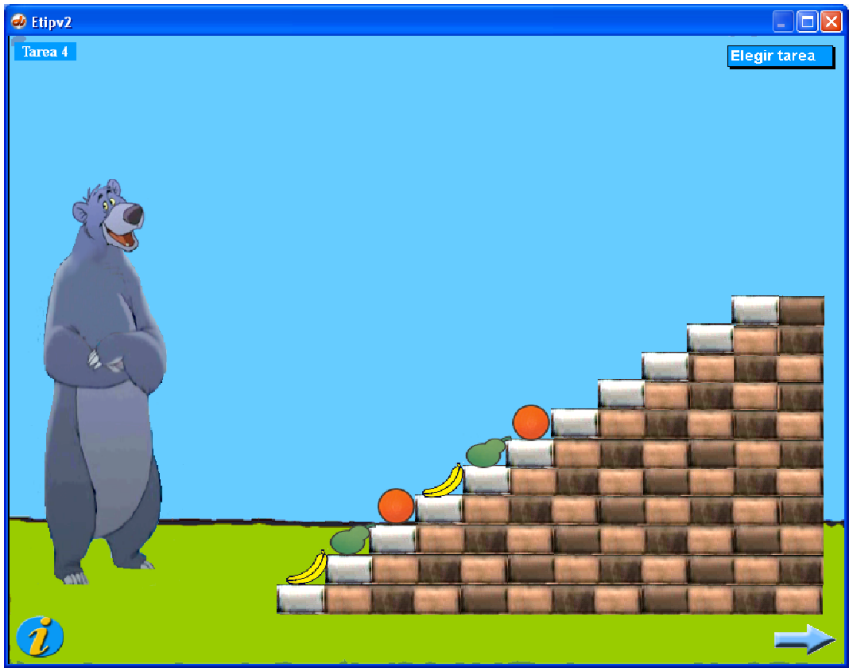
Labeling tasks



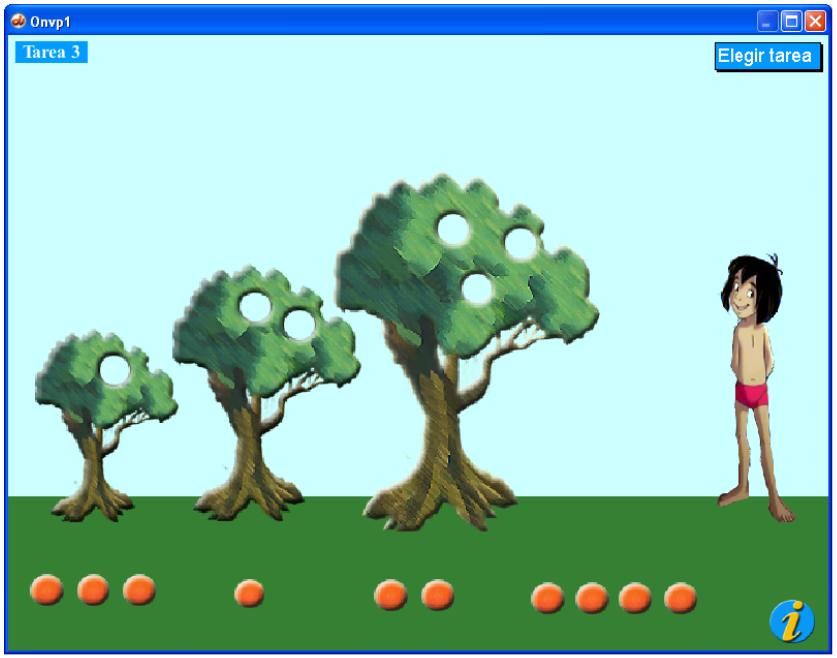
Audio: The audio message is common for all tasks, *"Look closely at the rungs. Each one has a fruit. In what rungs Baloo has hidden bananas? Clic where you think it should be."*.

They are seven non–verbal tasks:

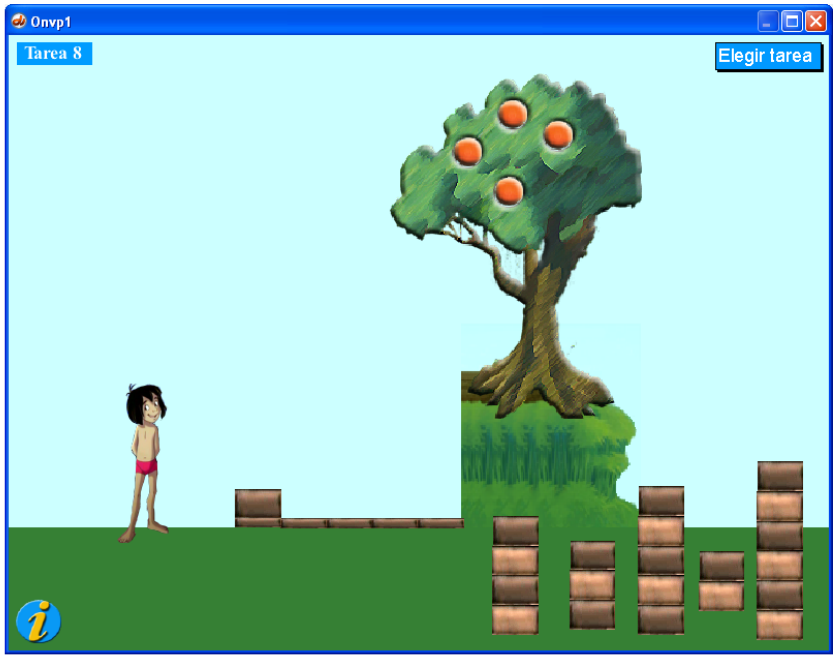
- **Introductory Task**: make sure that the children know the scene and the actions to take in subsequent tasks.
- **Tasks 1 and 2**: Detect, respectively, a cyclic alternating: yes–non–yes–non-yes–non. . . , and its opposite, and apply them to labeling, through the color, the positions the items are located.
- **Task 3 and 4**: Detect, respectively, cyclic alternations non–yes–non–non–yes–non–non. . . and yes–non–non–yes–non–non. . . . And apply them to labeling, in the absence of color, the positions the items are located.
- **Task 5 and 6**: Same as above but with reference to cyclical alternations of the type non-yes–non–non–yes–non. . . and non–non–yes–non–non–yes. . . .

Ordering on discrete quantities (1)

This set consists of two parts or subsets.



(a)



(b)

Audio: The audio message for the first four tasks (a) is *"Mowgli wants you put the oranges in the trees. Put each one in their place. But look at it carefully!"*. And for the last four (b): *"Mowgli wants to pick the fruits up the tree. To achieve this, help him putting the parts you need!"*.

Ordering on discrete quantities (2)

Subset(a): four non–verbal tasks.

- **Task 1**: to know the scene and the actions to take in subsequent tasks.
- **Tasks 2, 3 and 4**: Determine if the subject uses some sort of ordinal strategy, numerical or non-numerical and procedural when involved three groups of fruits (Task 2), four groups which you must choose three (Task 3), or five groups which four must be elected (Task 4), and in these cases, if you are able to discriminate extra element.

Subset(b): four non–verbal tasks also.

- **Task 5**: to know the scene and the actions to take in subsequent tasks.
- **Tasks 6, 7 and 8**: To determine whether or not the children place the pieces, using the tipified strategies, in a simple 1-2-3 seriation, using either the counting or progression of sizes of the pieces together with left-right laterality (task 6), in sequential order 1–2–3–4 (task 7) or in the order 1–2–3–4–5 (Task 8), looking both to the progressive number of rungs and to the number of blocks in each piece, and if he is able of discriminate the extra pieces in each case.

Recording data

To the **linear order and labeling tasks** has been stored all the information in the **records**:

- ***Location vij*** *(linear order) and* ***pij*** *(labeling).*
- ***Numbers of attempts nij.***
- ***Temporary records ti.***
- ***List of actions ListaRi***: list of pairs (vij, nij) (linear order) or (pij, nij) (labeling).

To the **Ordering on continuous and discrete quantities**, in the **records**:

- ***Location of action vij, vpi*** (wrong piece).
- ***Total numbers attempts nij, npi*** (wrong piece).
- ***Identification of attempts eij, epi*** (wrong piece).
- ***Numbers of failed, contradictory and null attempts neijk, ncijk, nnij, nepij, ncpij, nnpi***: erroneously placing valid pieces (the first three) or the wrong piece (the last three) or moves pieces without ever put in any hollow (zero attempts).
- ***Total numbers of failed attempts ieij, iei.***
- ***Temporary records ti.***
- ***List of actions ListaRi, listaAci, listaei***: total sequence of attempts and successful and wrong attempts sequences in the task.

Variables

The results presented are a small portion of total results of the study. The following variables are related only to the results presented.

The valuation

The valuation of the tasks was done by inspection of values contained in the lists of actions. We have assigned the **value 1** when the task is **correctly solved**. In the more **complex tasks with continuous and discrete quantities** (3, 4,7 and 8), we have assigned the **value 0.5** to the tasks that have been resolved with a **single error**. In **other cases** has been assigned the **value 0**.

Variables

In the dependent variables **SumL**, **SumEt**, **SumCC** and **SumCD** are stored, for each set of tasks, the sum of successful attempts made by each child, according to the previous valuation.
The **ML**, **MEt**, **MCC** and **MCD** are the corresponding averages obtained for the age groups and the **EDG** variable refers to the average ages of age groups.
For the dependent variables are used scales of five units in length.

Study development

Type of study:

Transversal qualitative-quantitative intentional study to explore tendencies.

Population and sample 1

Population

Urban estándar children from 3 to 7 years old and middle-low social class without conflicts neither social marginality problems.

Sample characteristics

- 2 Centres: Intentional election from Prekindergarten and Primary schools of Málaga city (with computer classrooms and enough number of students).
- Initial sample size: 132 students.
- Stratified sampling with 8 age groups, from 3 and half years old to 7 years old by intervals of 6 months:
  - Kinesthetic basic aptitudes.
  - Appropriate size of groups to analize data.
- Final sample size: 76 students.

Population and sample 2

Sample final composition

GED	N	Average	Tipic error of average	Tipical Desv.
3AM	10	3,5500	,03578	,11314
4A	10	4,0300	,04326	,13679
4AM	10	4,4960	,04167	,13176
5A	10	4,9970	,04648	,14697
5AM	10	5,4940	,04812	,15218
6A	10	5,8820	,03702	,11708
6AM	8	6,4638	,03669	,10378
7A	8	7,0800	,07375	,20860
Total	76			

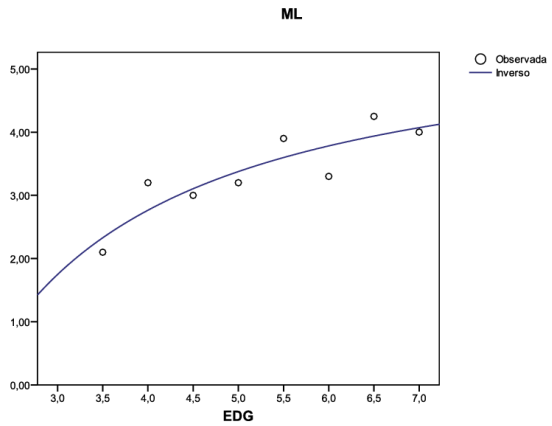
Statistic parameters of the sample

Development Highlights

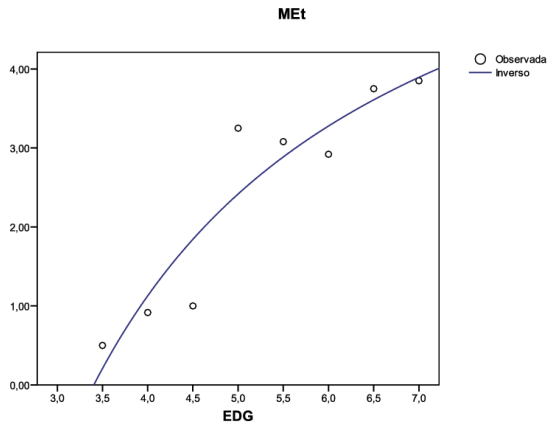
- Each subject performed the tasks sequentially, with unlimited time.
- The order followed was: linear order tasks, tasks of order with continuous quantities, labeling tasks and tasks of order with discrete quantities.
- In the fourth set of items, each subject responded to a verbal questionnaire to identify possible strategies used.
- The researcher only took part to assist the subjets occasionally (when the mouse was poorly placed on the table), to develop the questionnaire, to collect the verbal responses and to record the information.

Results and Conclusions

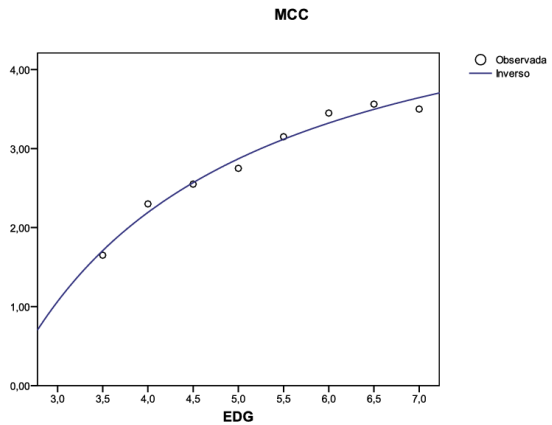
Observed and fitted values



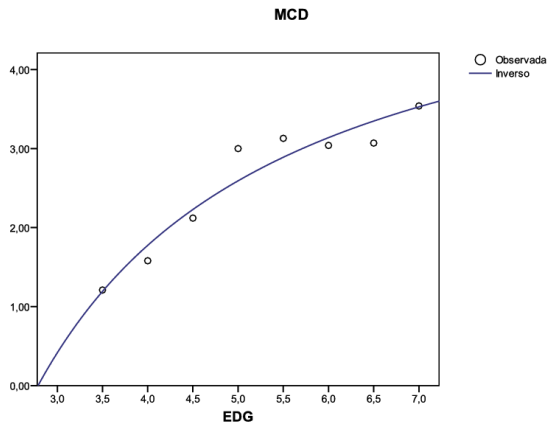
1-Linear order



2- Labelling; ordered positions



3-Order bt Continuous quantities

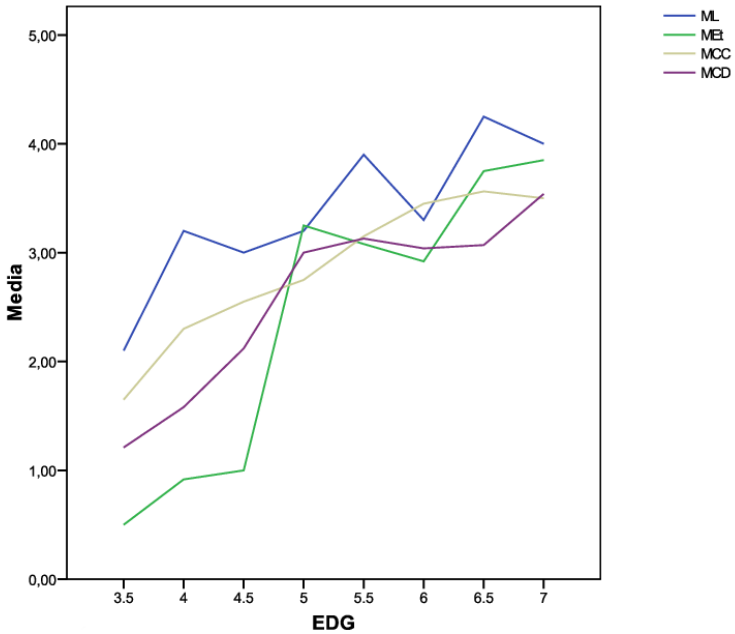


4-Order bt discrete quantities

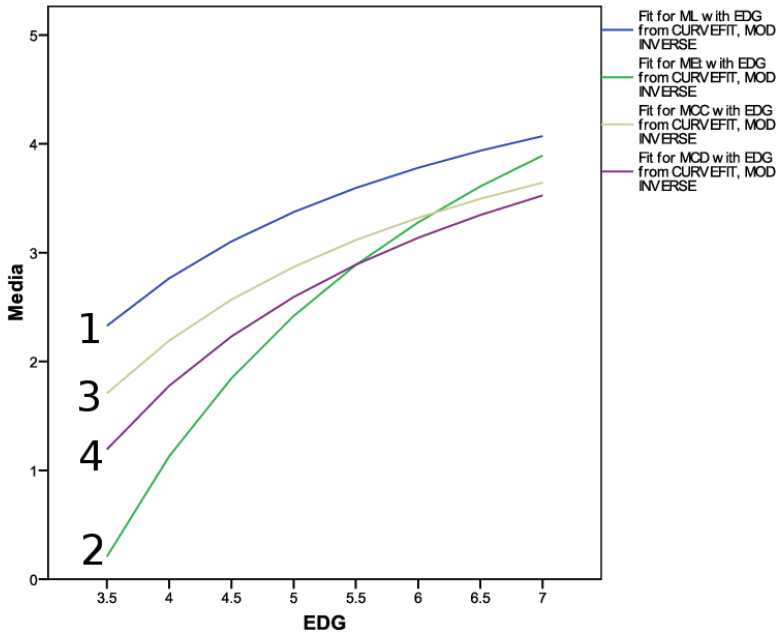
Means of responses by age to the tasks of each one of the four sets of items and the corresponding fitted curves by means of the non linear regresion inverse model:

$$y = a + \frac{b}{x}$$

Comparative analysis



Observed values



Fitted values

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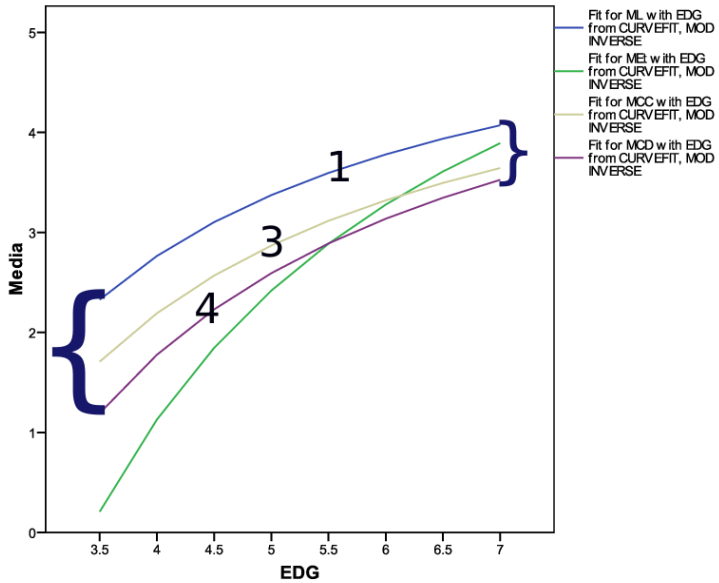
Conclusion 1

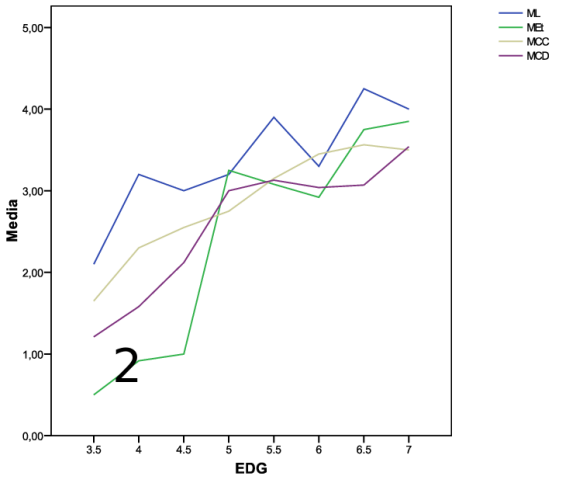
The evolution of ordinal competencies agree with the model proposed.

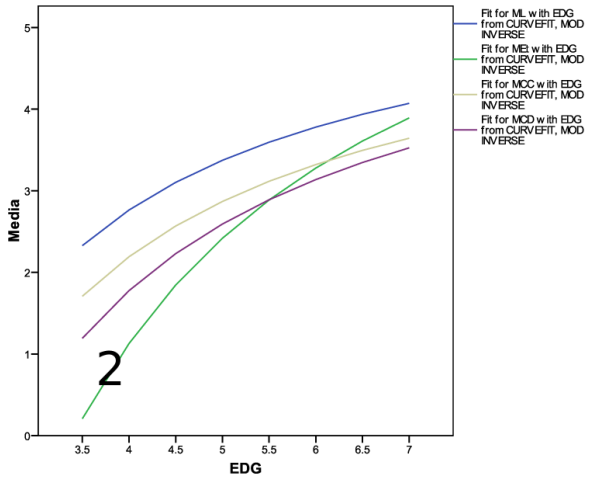


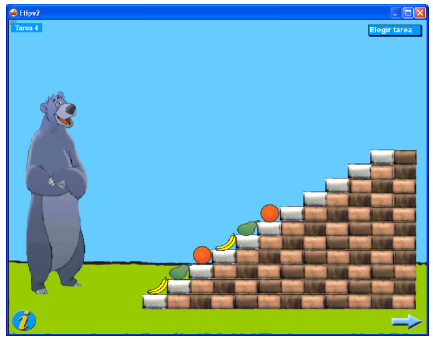
- It can be observed a similar behavior and evolution, according to the proposed model, of competencies related to categories 1 (Linear Order), 3 (Order between continuous quantities) and 4 (Order between discrete quantities).
- Also the differences between categories decrease as age increases.
- Finally, are remarkable the highly closed relations between order skills with discrete and continuous quantities. This result is claiming for a jointly didactical treatment of both types of quantities and measures from 3 to 7 years old.

Conclusion 2

The responses to the tasks of labeling show a different pattern; these are more than ordinal tasks.







- There is a significant gap between the results from four to five years old which can not be attributed to azar.
- Further analysis reveal that these tasks are involving something more than ordinal competencies, such as some inductive reasoning skills or certain prealgebraic ideas (to identify inductive patterns and to apply it for continue a series).

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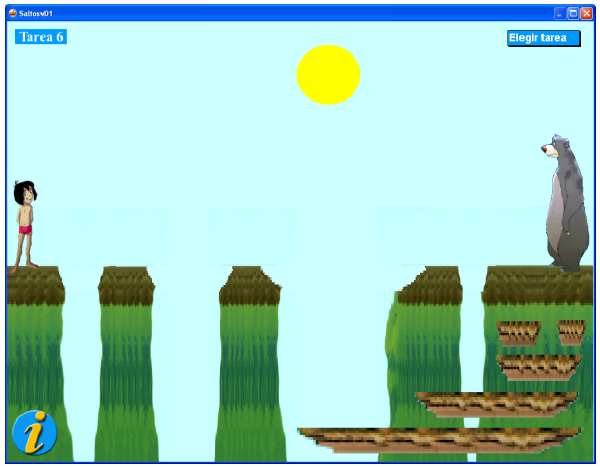
Conclusion 3

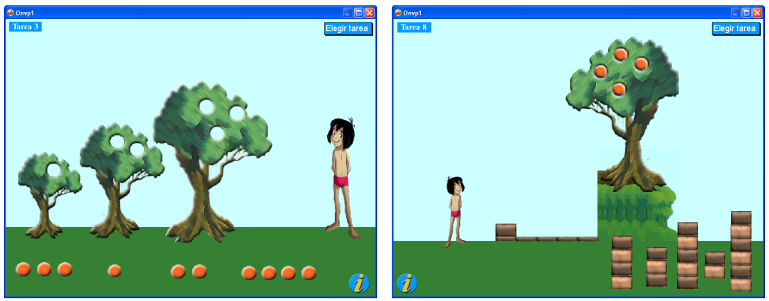
Multimedia technology is a good scenario to build a relevant and valid research methodology in mathematics education in early stages (the subjects point of view).



- Multimedia technology allows the implementation of meaningful tasks that come into play cognitive, visual-spatial and affective-emotional abilities.
- The integration of various multimodal elements get higher quality scenarios for research with young subjects and well suited to his cognitive and psycho-affective characteristics (97.37% completed the tasks proposed).
- Multimedia scenario is dynamic, playful, responds to the actions expanding the everyday world, encourages motivation and captures the attention to ensure the involvement and active participation.

Conclusion 4

Multimedia technology is a good scenario to build a relevant and valid research methodology in mathematics education (the amount, objectivity and accuracity of information and results).



(a) (b)

- Is a good data collection and storage tool.
- Minimizes the interaction between the researcher and the subjects, preserving autonomy and attention and stimulating the imagination.
- Using the web pages format and the connection to databases it can be raised further mass studies.

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