Multisensory Learning In Adaptive Interactive Systems

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Dibris

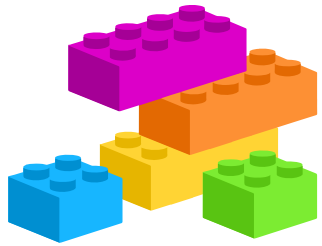
We DRAW

Who I am

2016
MSc Cognitive Science

2016
PhD candidate in Computer Science

2020
Research Fellowship



From cognition to technology

- ✓ multisensory perception and performing arts may have a role in enhancing learning
- ✓ neuroscience research highlights the role of specific sensory modalities and their integration in learning specific tasks, especially in developmental years.
- ✓ technology does not integrate this knowledge in its design

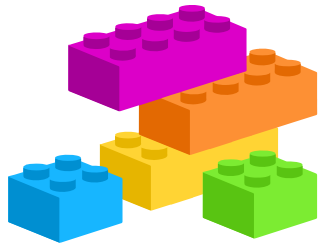
Multisensory learning

Multisensory perceptual learning and cross-modal generalization has been reported, where stimuli share some common characteristics (Bartolo and Merchant, 2009).

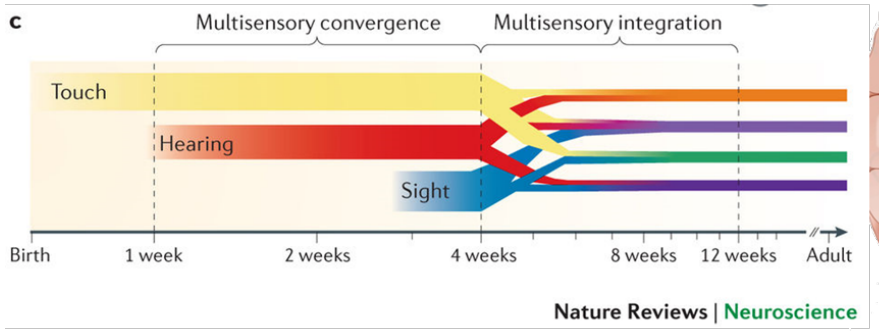
The salient characteristics for a given task are more likely to be generalized across modalities (Jain et al., 2010).

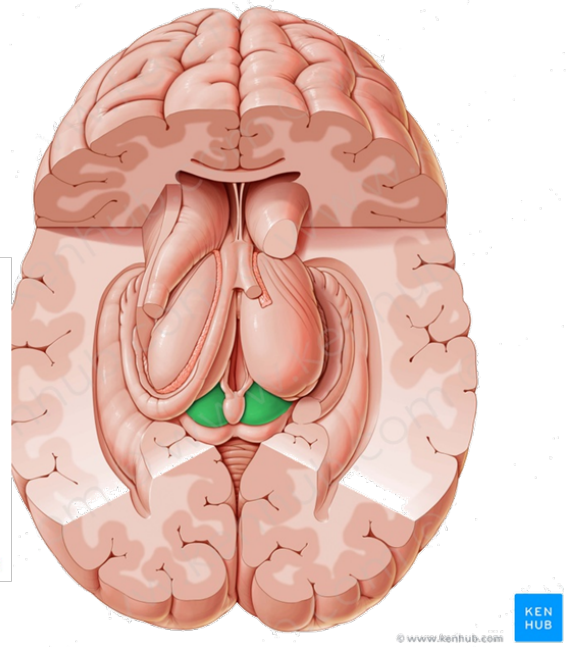
Multisensory processing and information

The synergy, or interaction, between the senses and the fusion of their information content is called "multisensory integration" (Meredith, 2002).



Multisensory learning

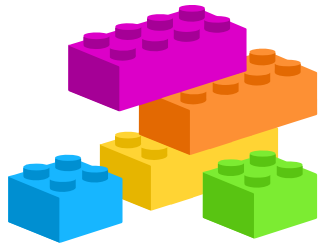




Where?

Superior colliculus neurons are multisensory, i.e. they respond to stimuli coming from more than one sensory mode.

Development of multisensory integration from the perspective of the individual neuron Barry E. Stein, Terrence R. Stanford & Benjamin A. Rowland **Nature Reviews Neuroscience** volume 15, pages 520–535 (2014)



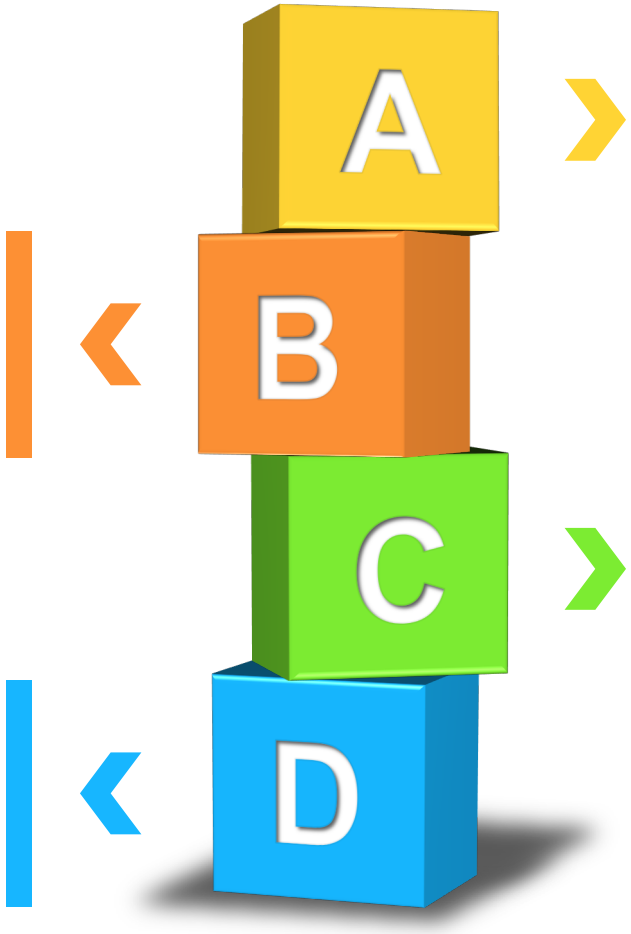
Research Questions

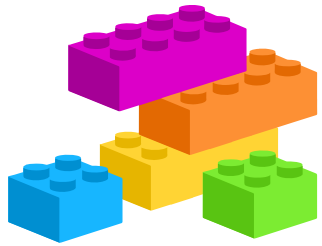
A. Which sensory modalities enhance embodied understanding and proprioceptive feedback in full-body learning tasks?

B. Does users' non-verbal behaviors be relevant in learning?

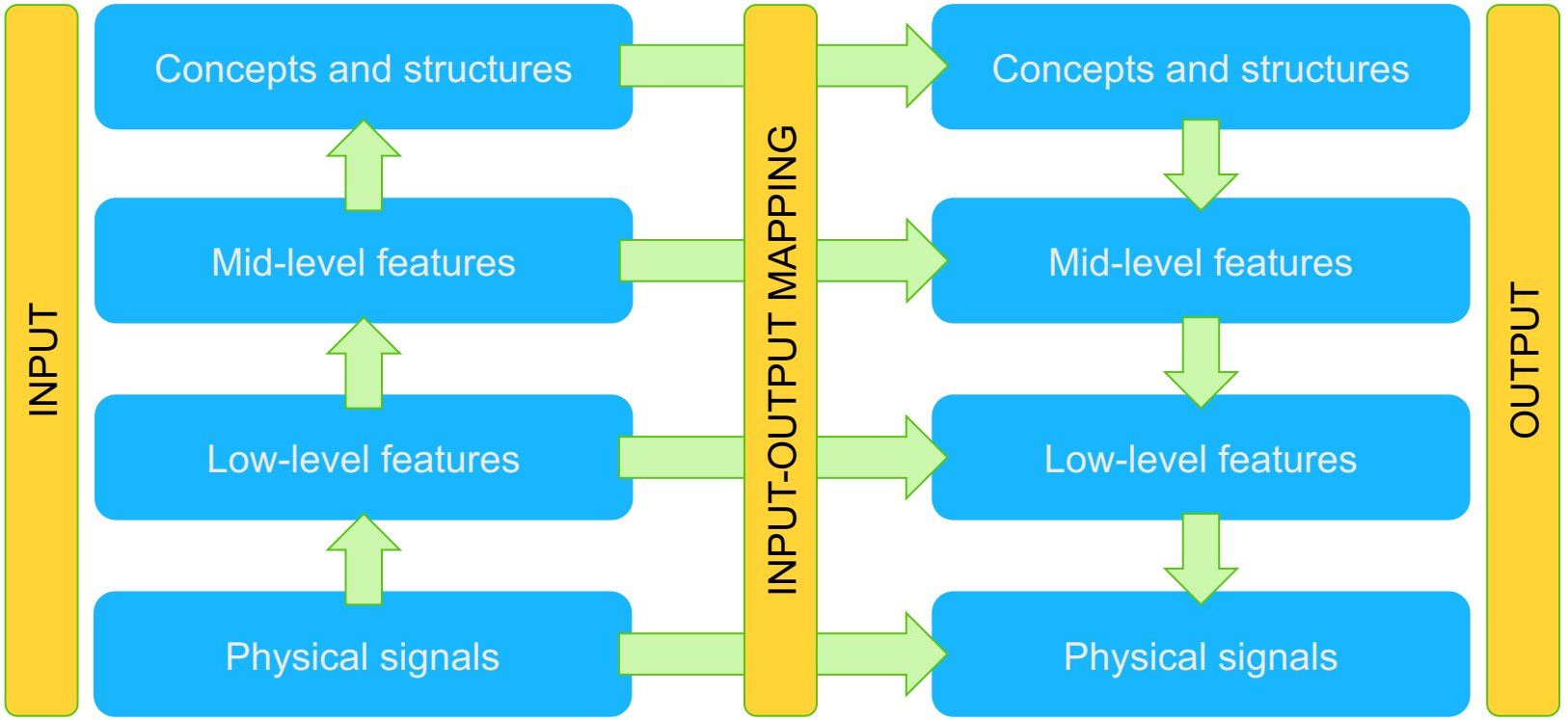
C. What cognitive states effectively support learning, both in children and adult? Can we automatically detect them?

D. How multisensory technology should be designed to proper enhance learning outcomes? How do we evaluate its efficacy?



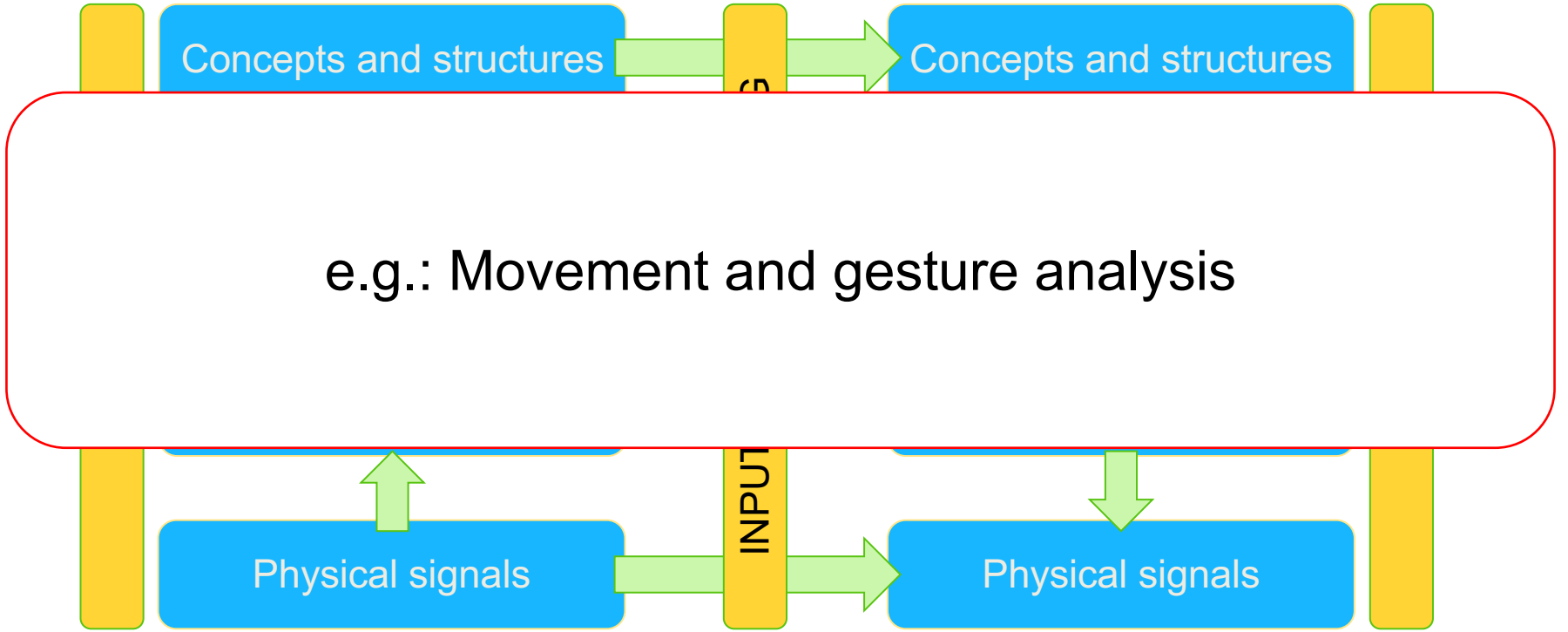


Computational model:
adaptive multimodal system

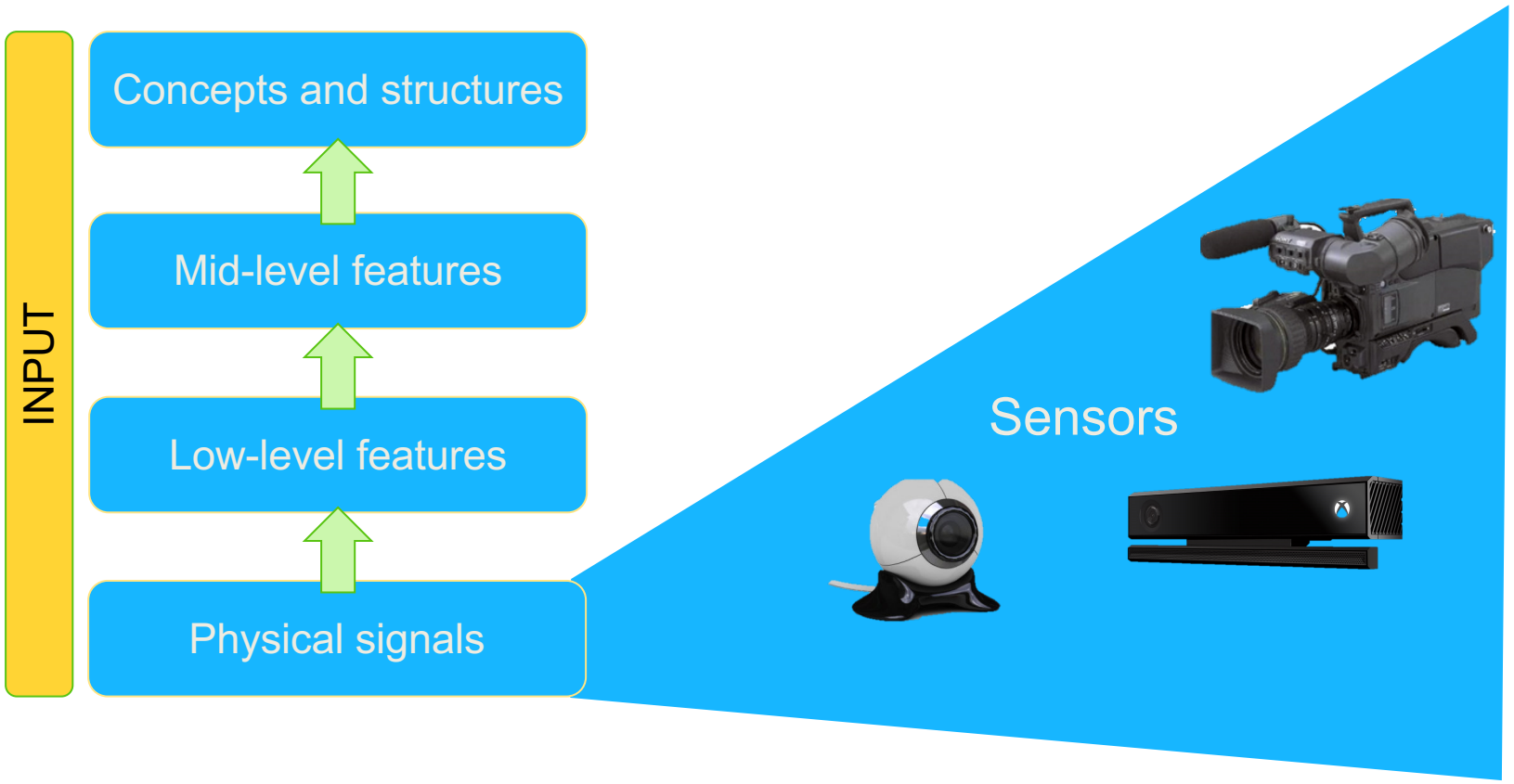


Camurri, A., Mazzarino, B., Ricchetti, M., Timmers, R., and Volpe, G., 2004. *Multimodal analysis of expressive gesture in music and dance performances*. In A. Camurri, G. Volpe (Eds.), Gesture-based Communication in Human-Computer Interaction, LNAI 2915, 20-39.

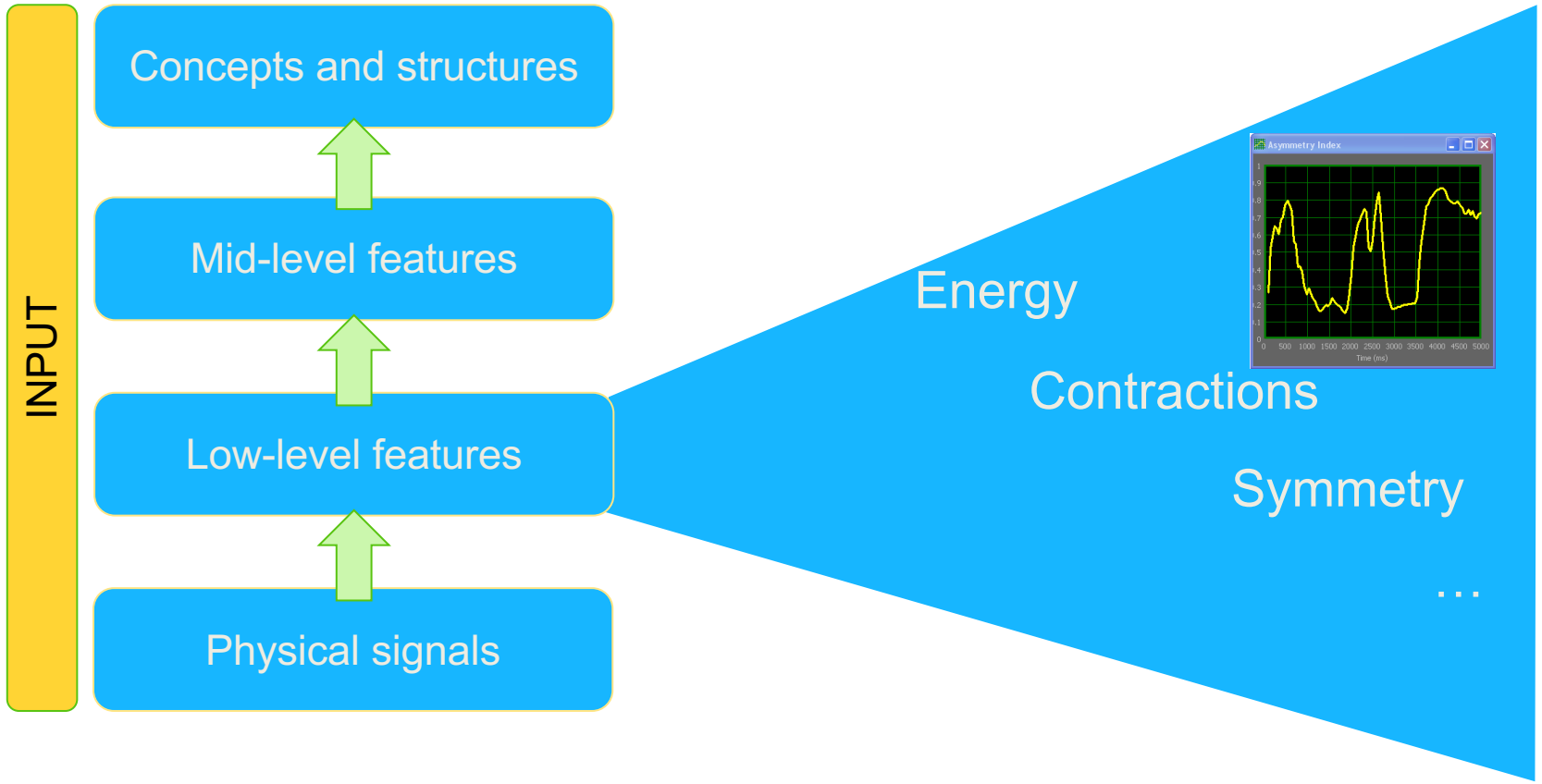
Adaptive multimodal system



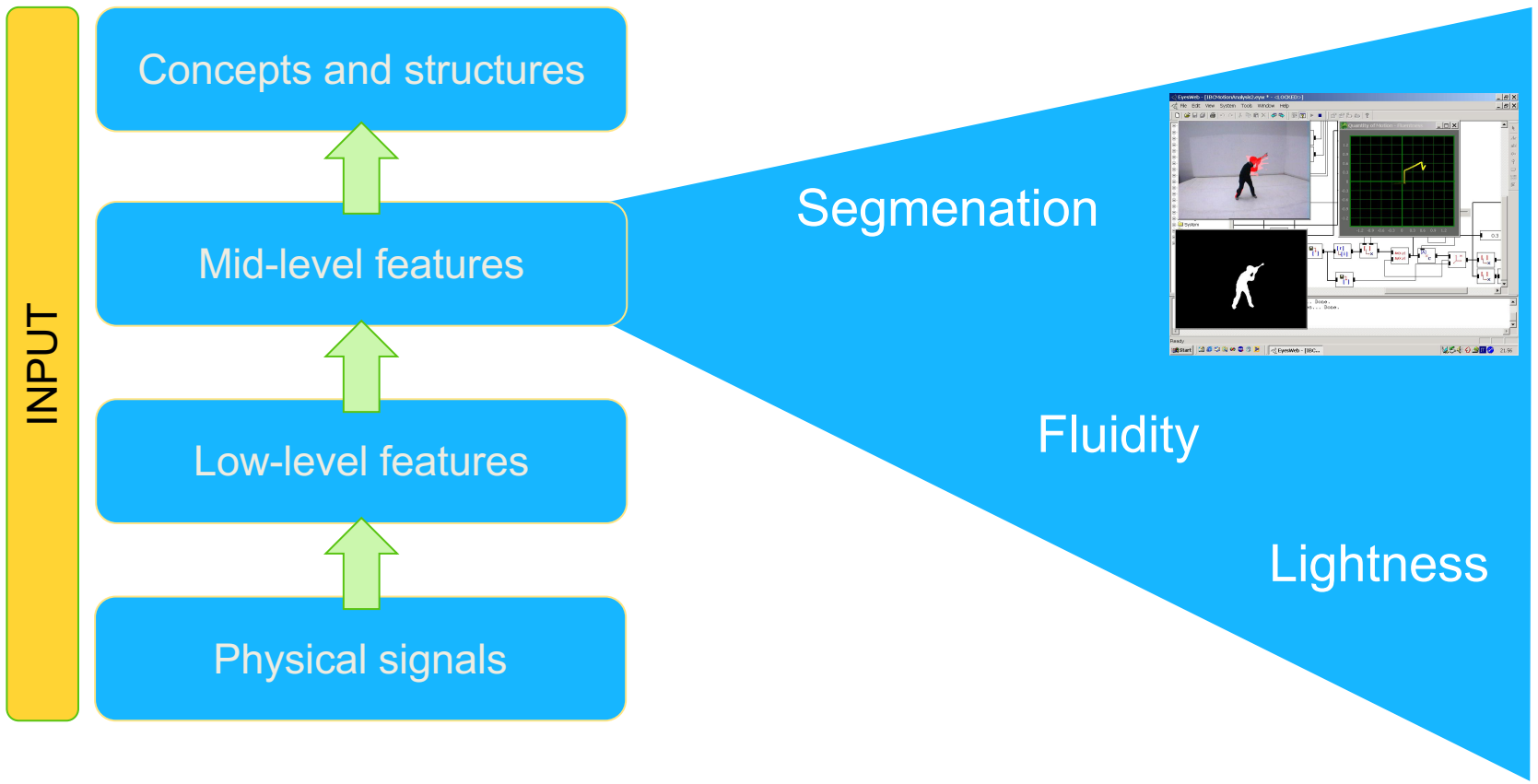
Adaptive multimodal system



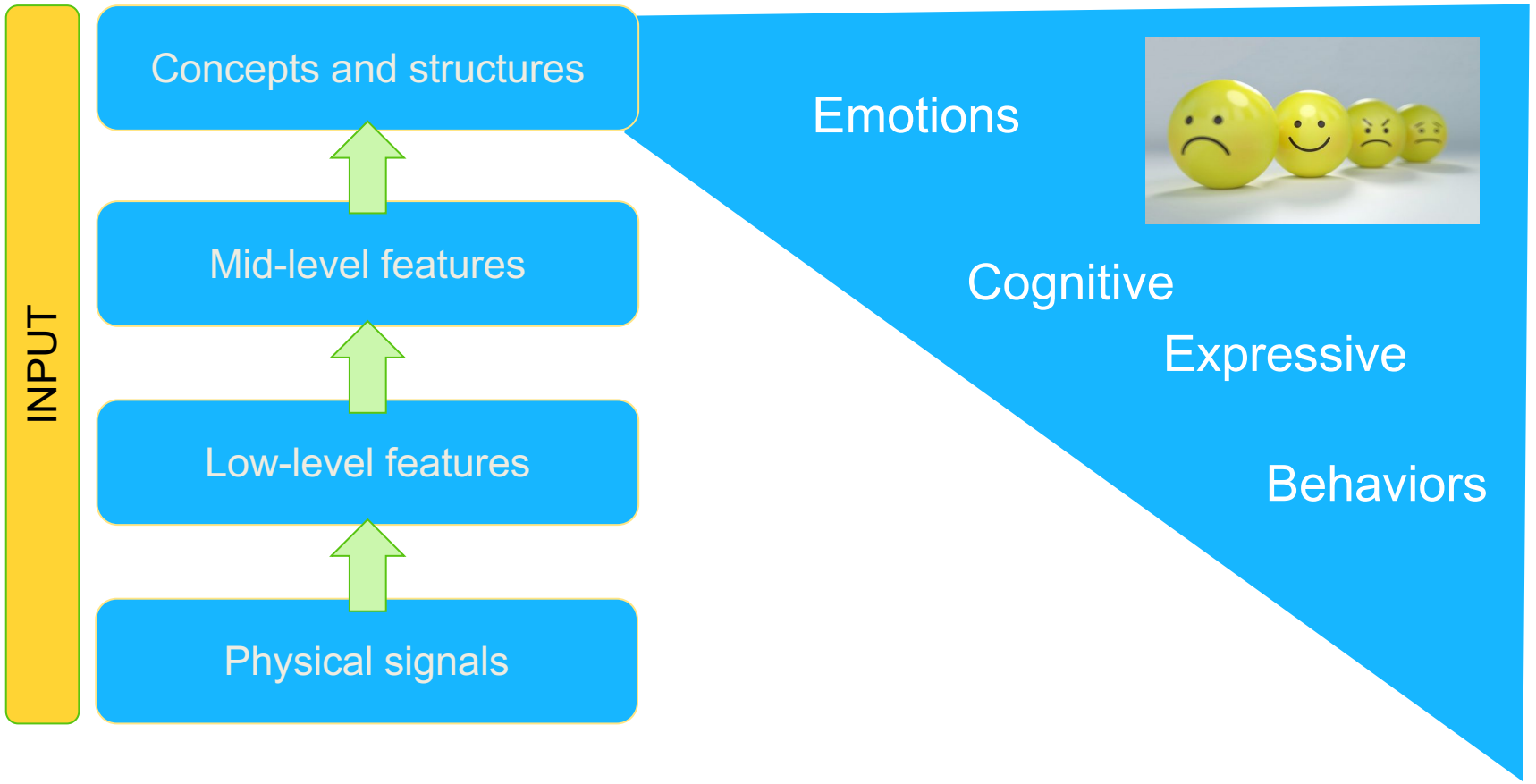
Adaptive multimodal system



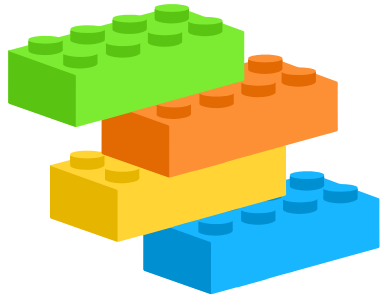
Adaptive multimodal system

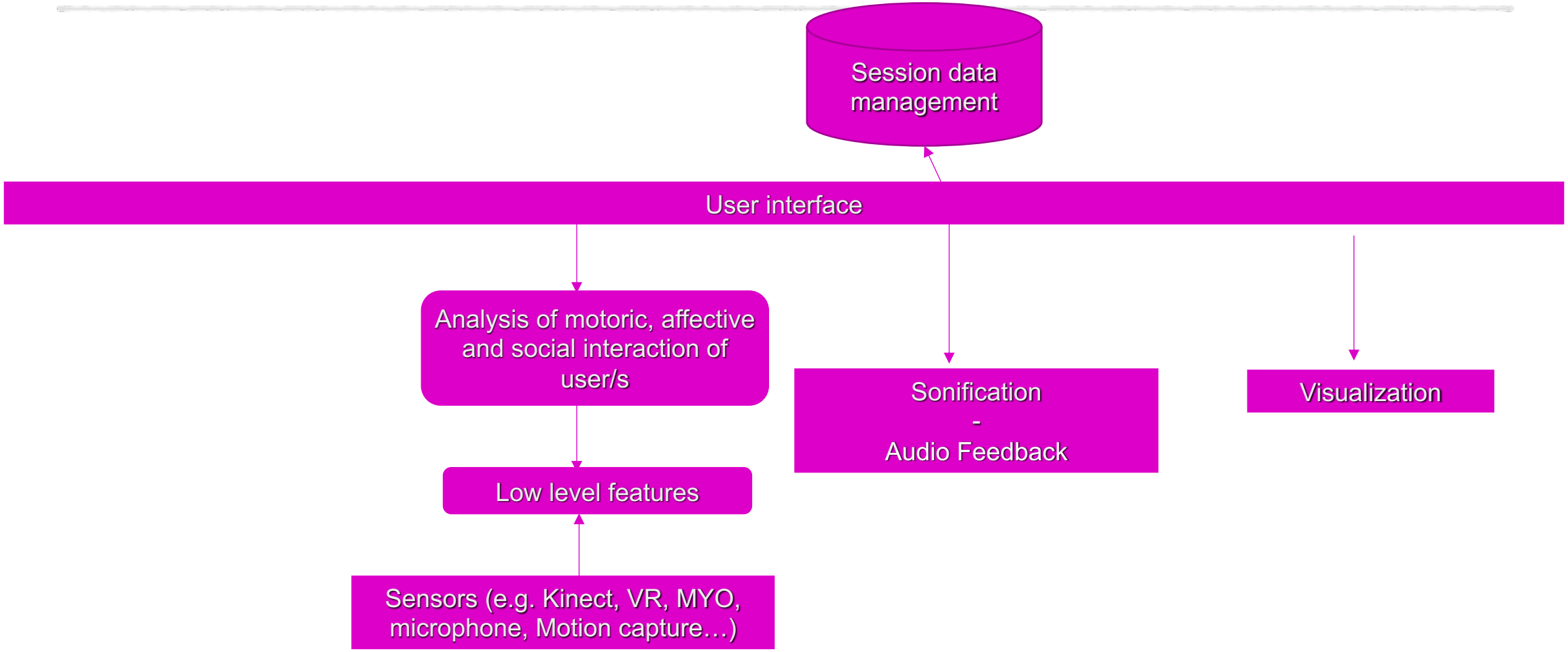


Adaptive multimodal system

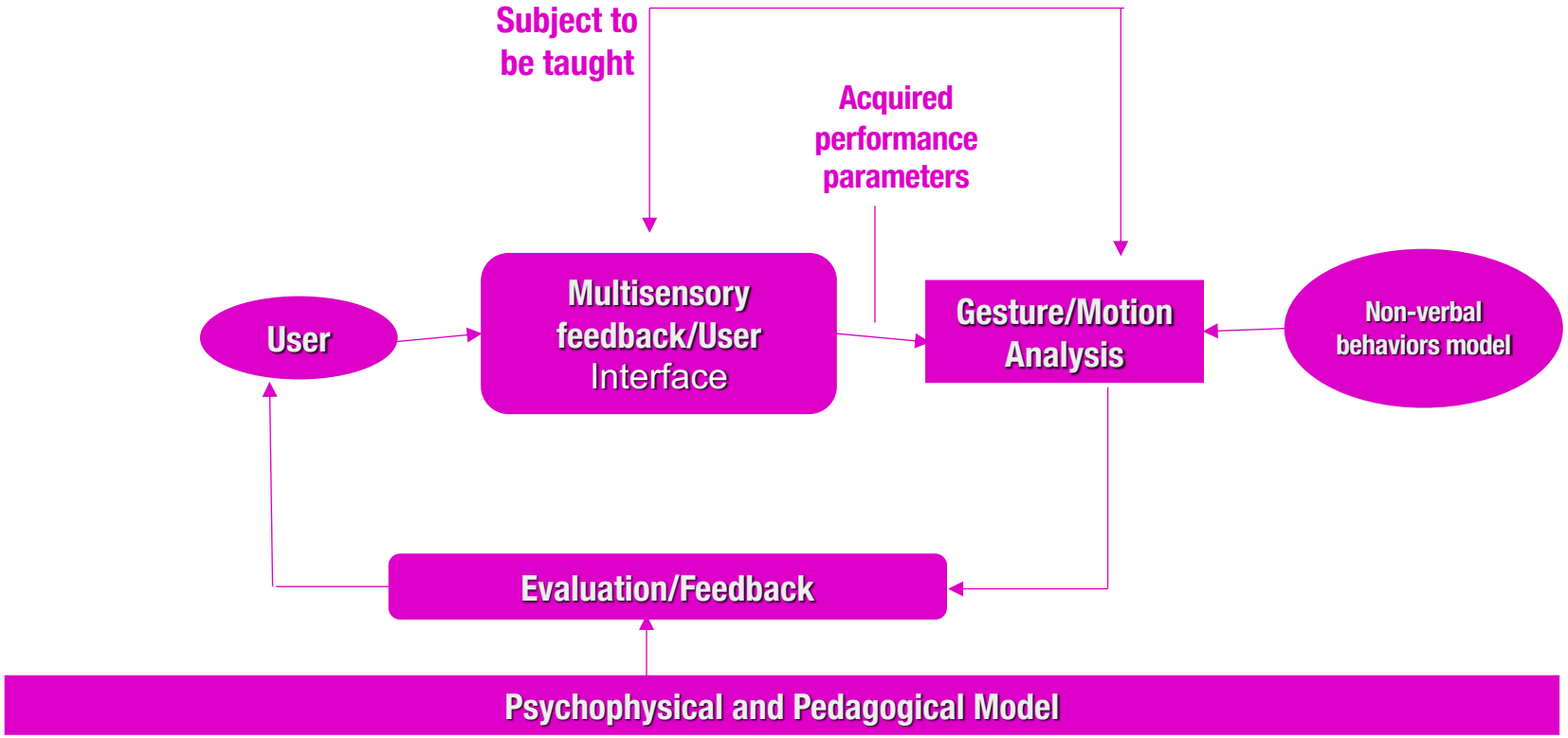


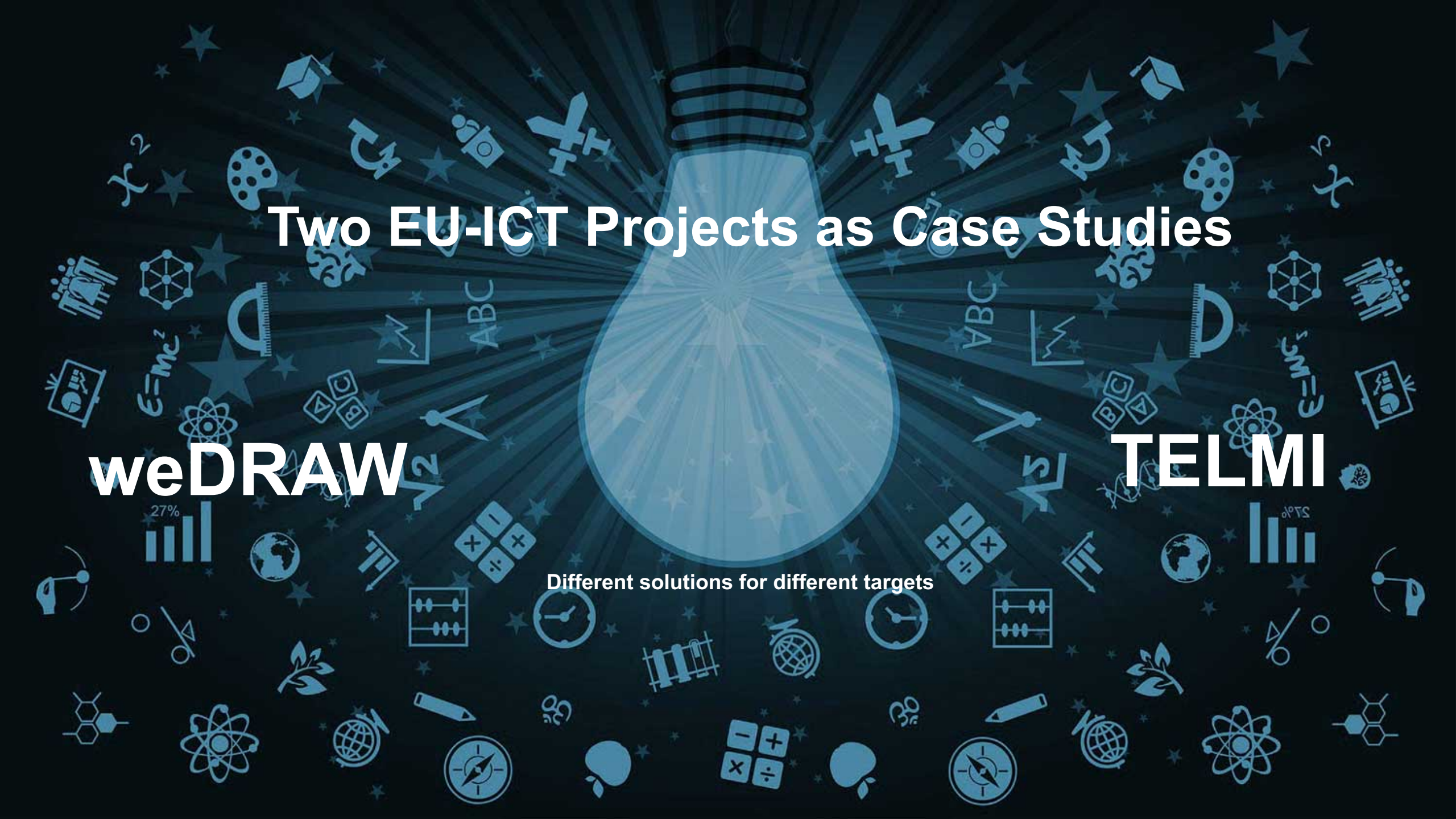
System architecture





Feedback model




Two EU-ICT Projects as Case Studies
weDRAW
TELMI
Different solutions for different targets

Why weDRAW and TELMI?

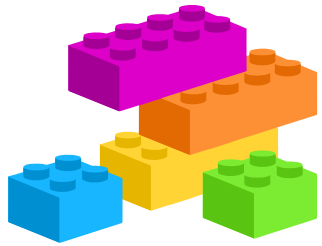
Music playing is a multisensory, embodied and social activity by its definition (Dalcroze, 1930).

Developmental studies point out the close relationship between bodily movement and musical sounds (Stern, 1985; Papousek, 1996).

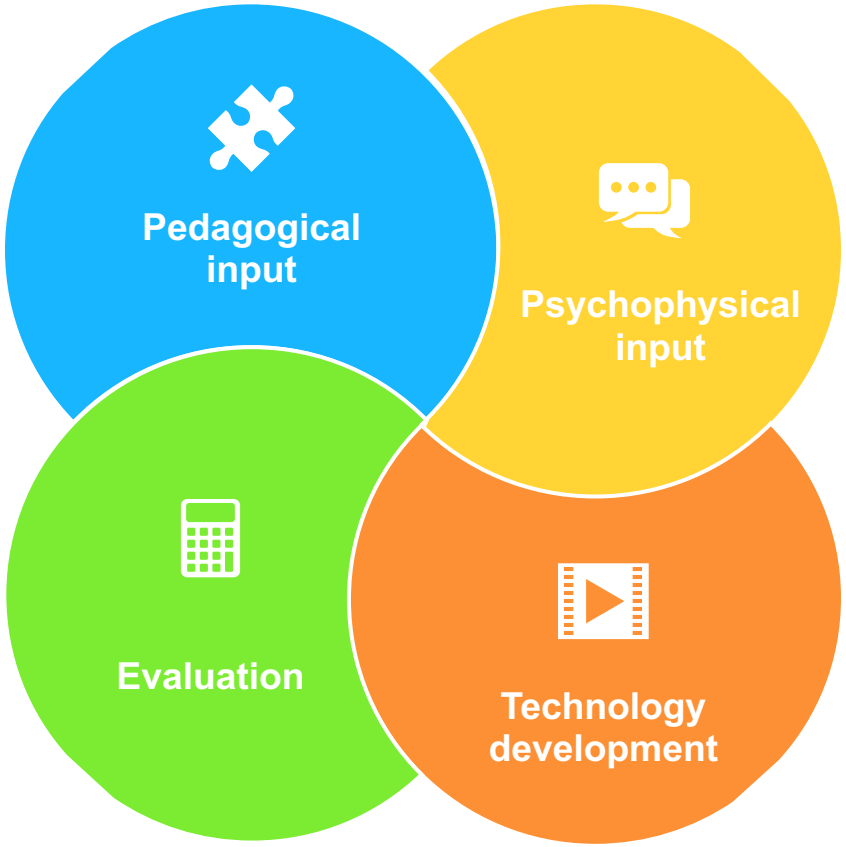
weDRAW

EXPLOITING THE BEST SENSORY MODALITY FOR LEARNING ARITHMETIC AND GEOMETRY AT PRIMARY SCHOOL

A novel approach to design unique serious game environment that suits both for typically develop children and for sensory impaired ones (e.g. visual impaired and dyslexic children)



Methodology



Highly **multidisciplinary** with an **integrated** approach

Pedagogical input

Identification of the arithmetic and geometric concepts to be learned at different ages and levels.

Psychophysical input

Identification of the most suitable sensory modality for perceiving and learning the arithmetic and geometry concepts pedagogues identified.

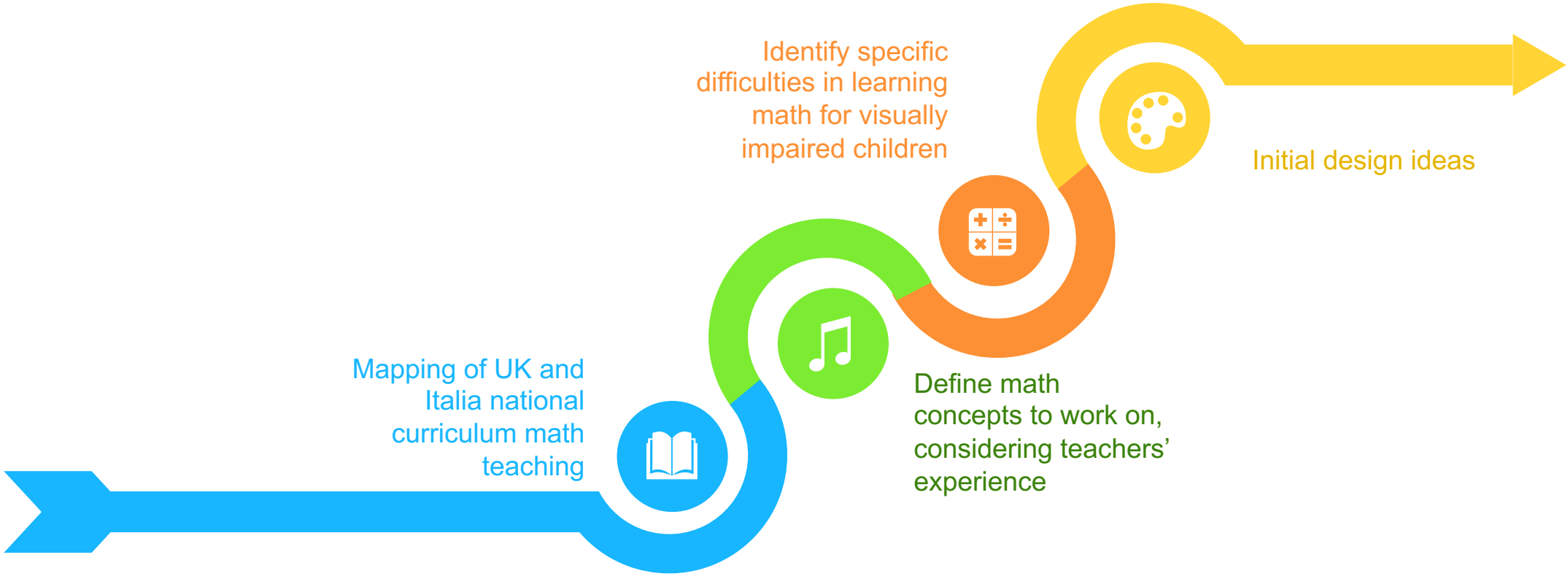
Technology development

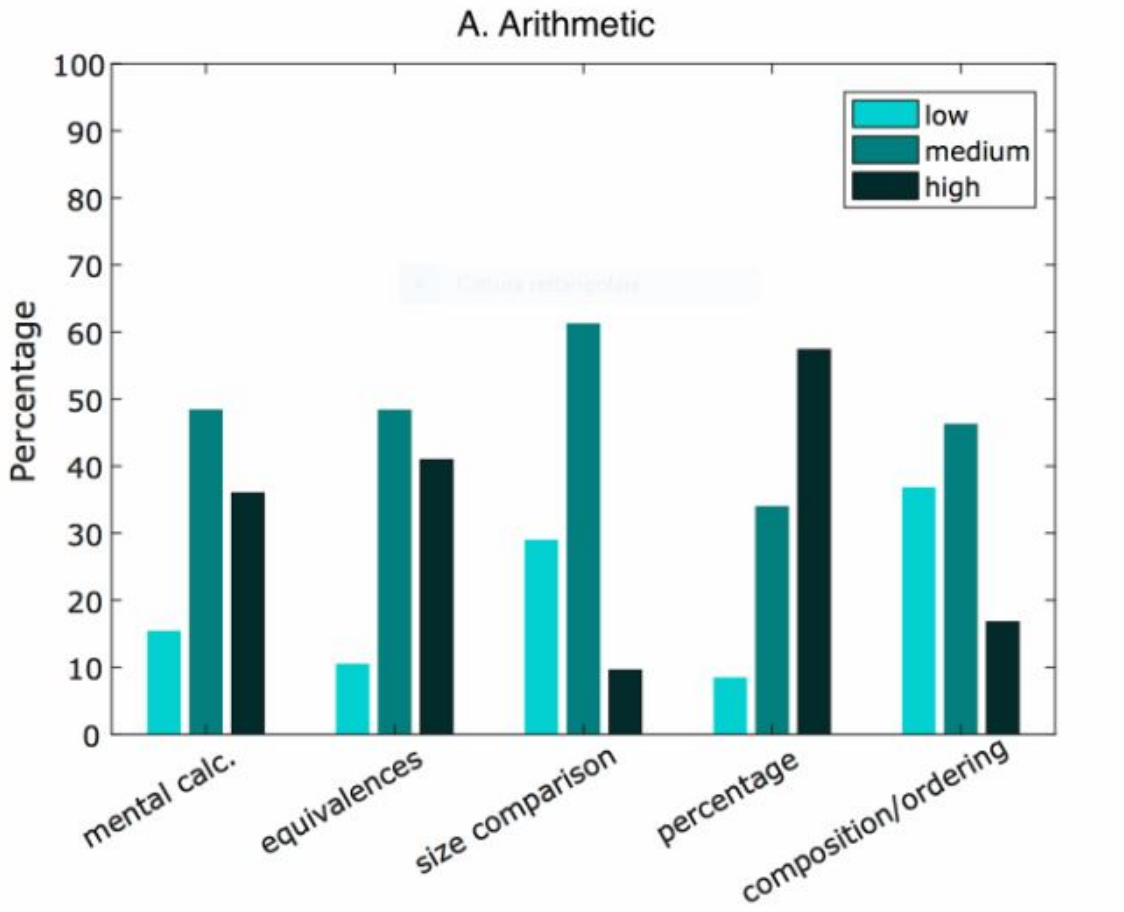
Two major pillars: (i) **user-centric iterative participatory design** and (ii) **early and fast prototyping**.

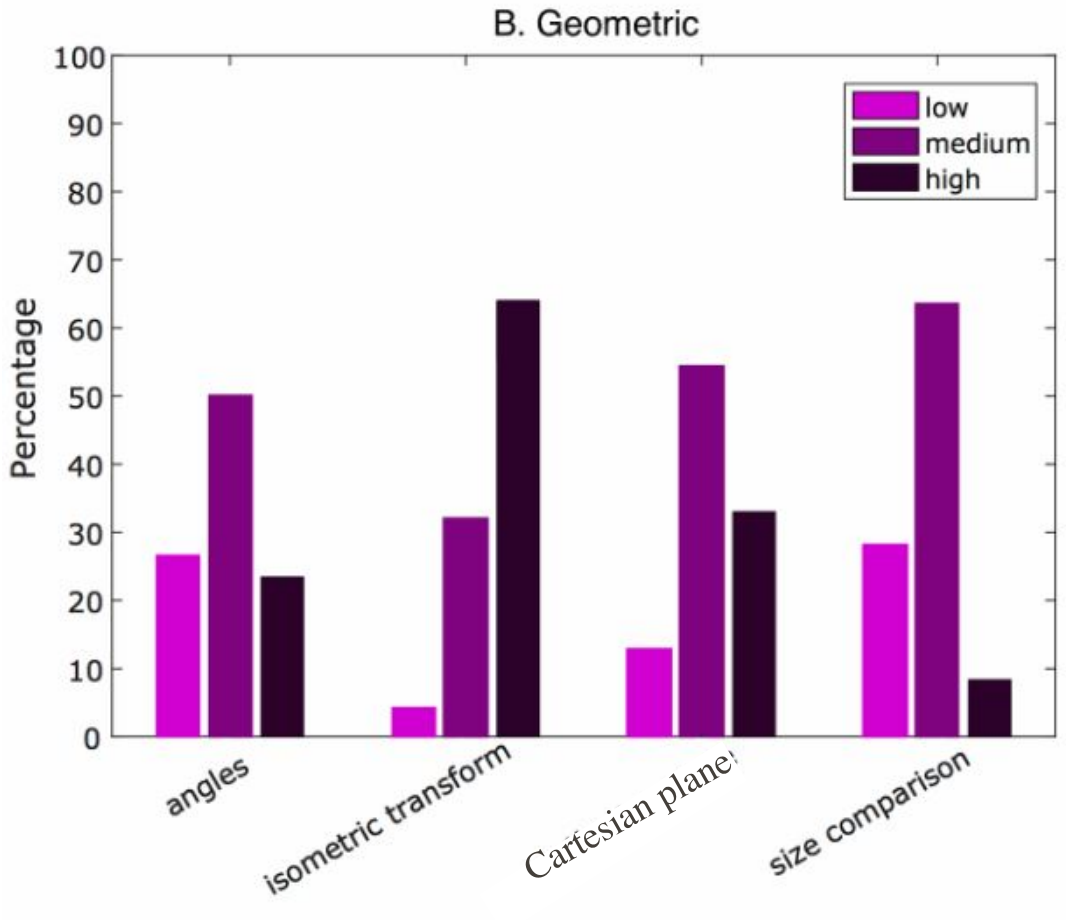
Evaluation

Metric and **performance indicators** are identified in order to assess whether the project reached its pedagogic, scientific, and technological objectives.

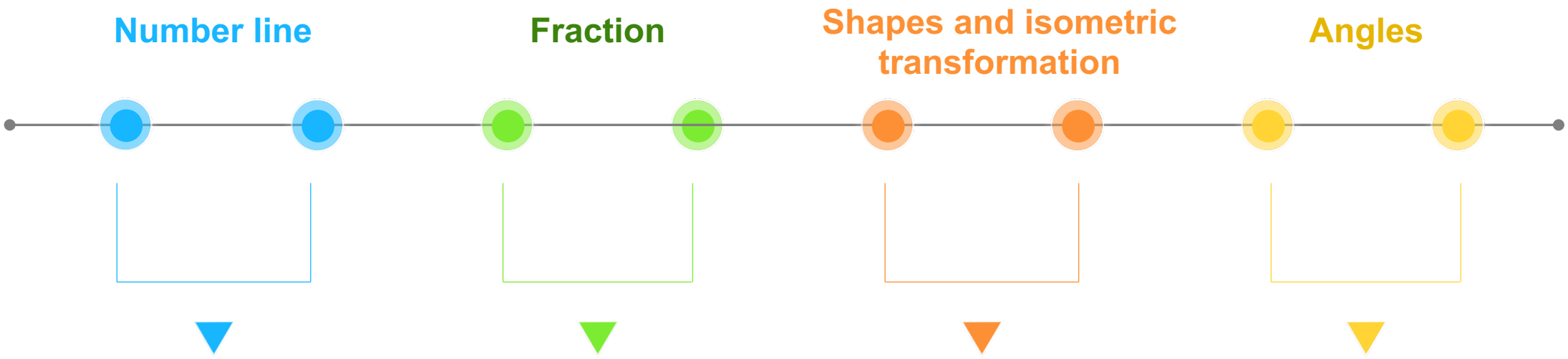
Pedagogical consideration

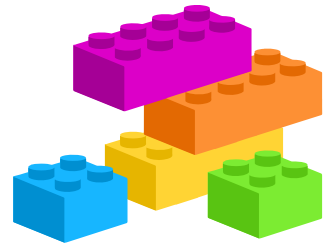



A. Arithmetic
Percentage
100
90
80
70
60
50
40
30
20
10
0
low
medium
high
mental calc.
equivalences
size comparison
percentage
composition/ordering


B. Geometric
Percentage
100
90
80
70
60
50
40
30
20
10
0
low
medium
high
angles
isometric transform
Cartesian plane
size comparison

Which sensory modalities for which concepts





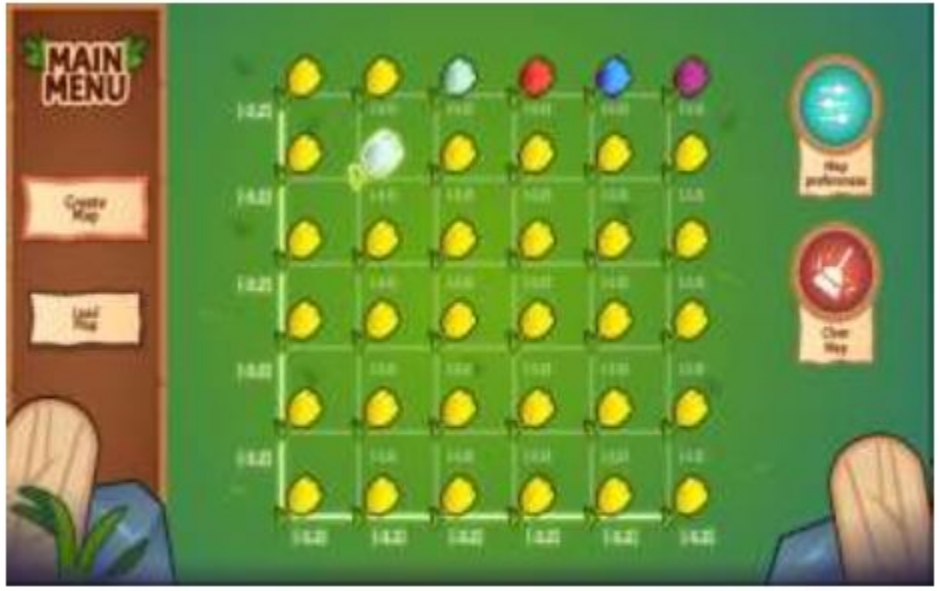
Volta, E., Alborno, P., et al. 2018. Enhancing children understanding of mathematics with multisensory technology. In Proceedings of the 5th International Conference on Movement and Computing (MOCO '18). ACM, New York, NY, USA, Article 50, 4 pages. DOI: https://doi.org/10.1145/3212721.3212889

MusicFraction Game

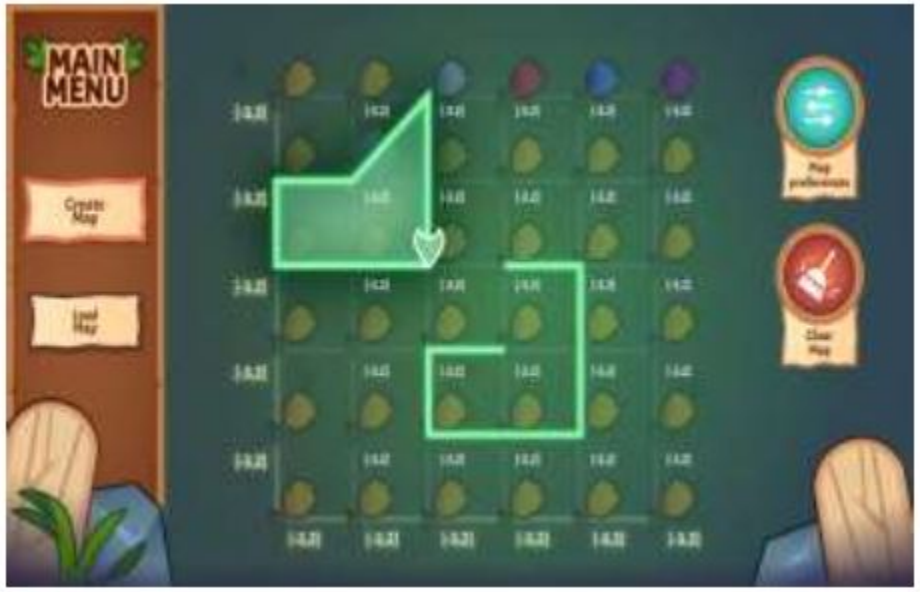
video

AngleShapes Game

video



TargetCoordinates mode



DrawShape mode

Cartesian Garden: 3D side view

Cartesian Garden: 3D top views

IgnitionFactory
Learn and Play for change

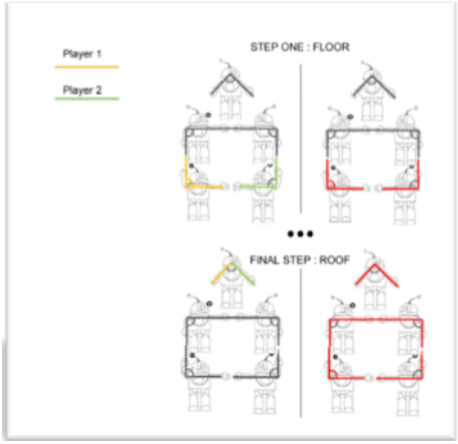
video

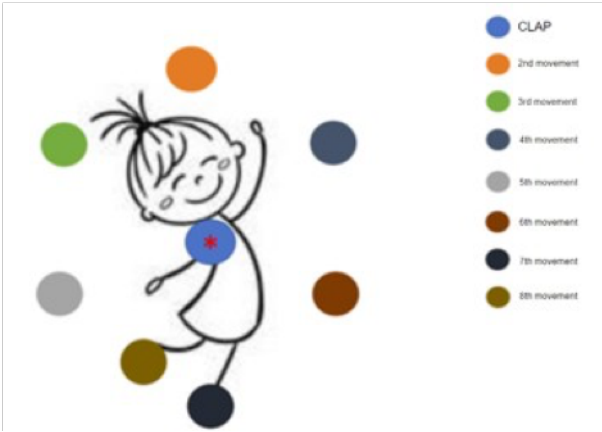
CartesianGarden Game

Social Activities Prototyping

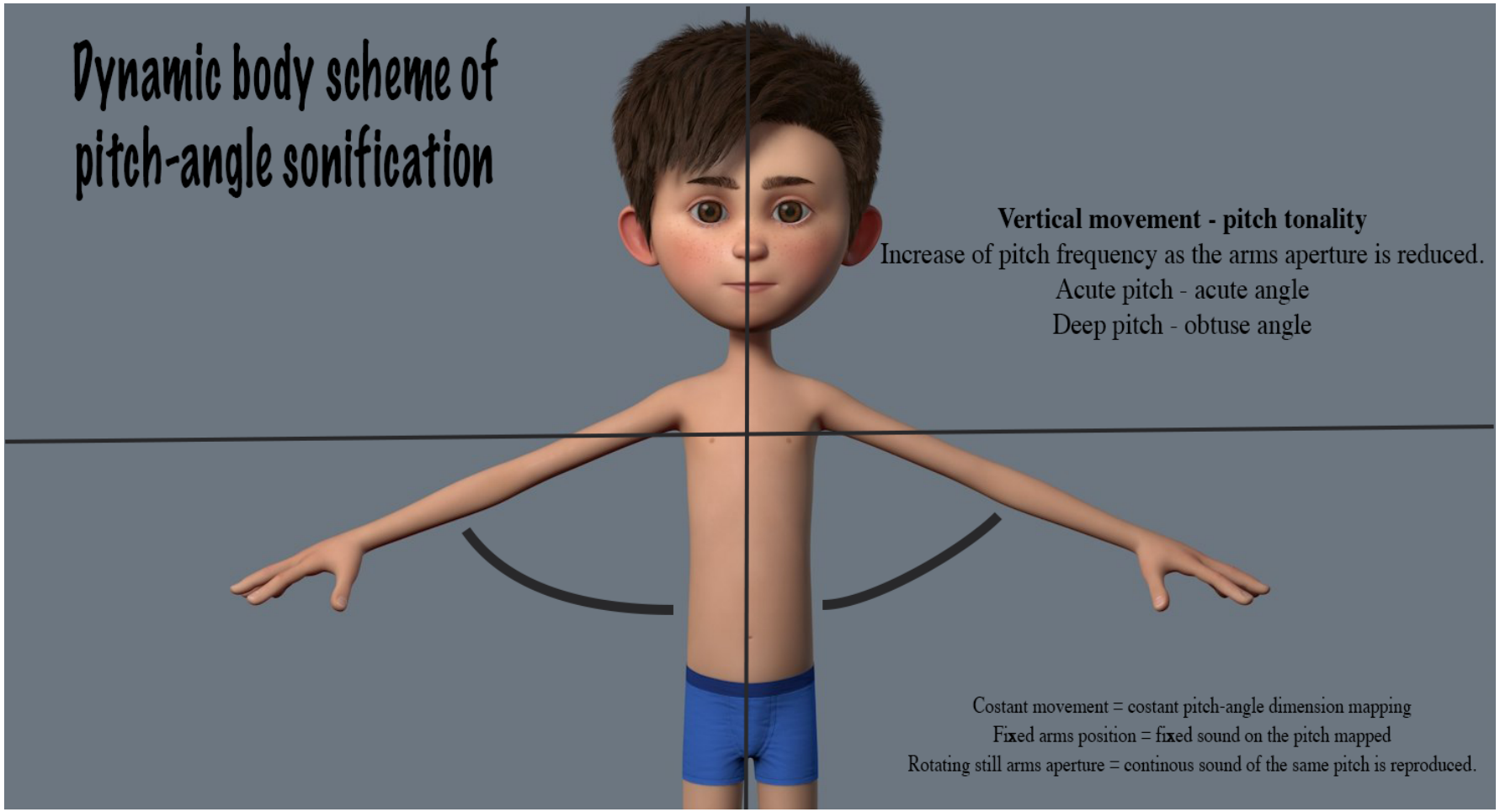
Volta, E., Alborno, P., Gori, M., & Volpe, G. (2018, August). Designing a Multisensory Social Serious-Game for Primary School Mathematics Learning. In 2018 IEEE Games, Entertainment, Media Conference (GEM) (pp. 1-9). IEEE.

IgnitionFactory



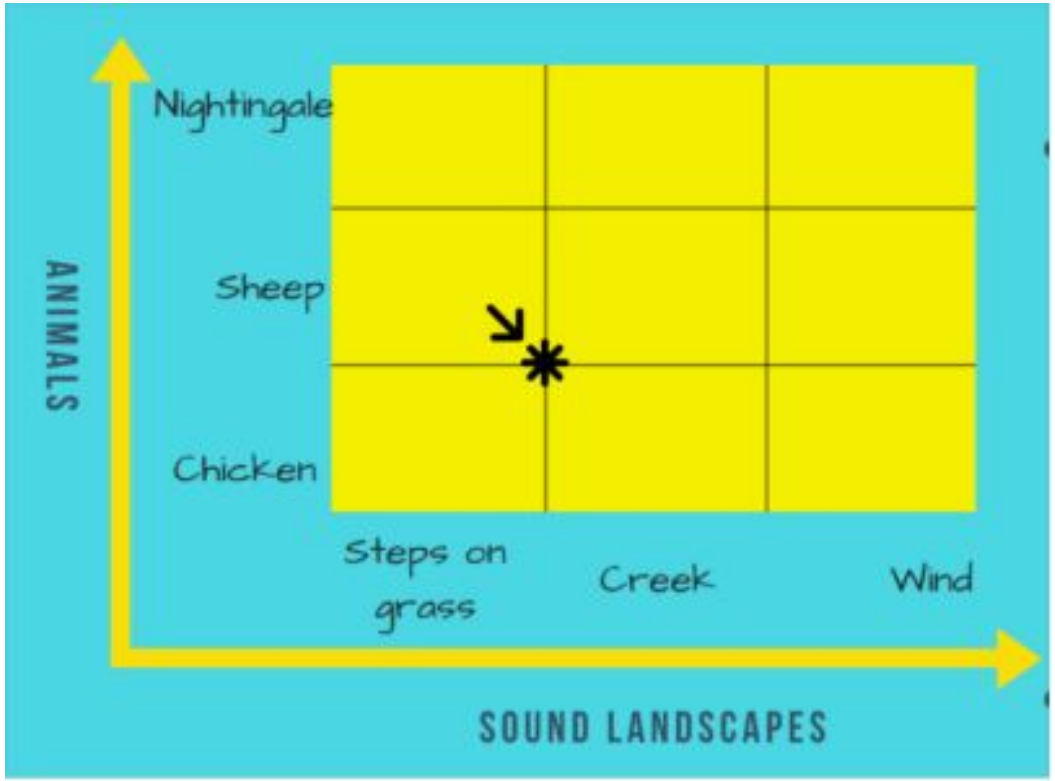


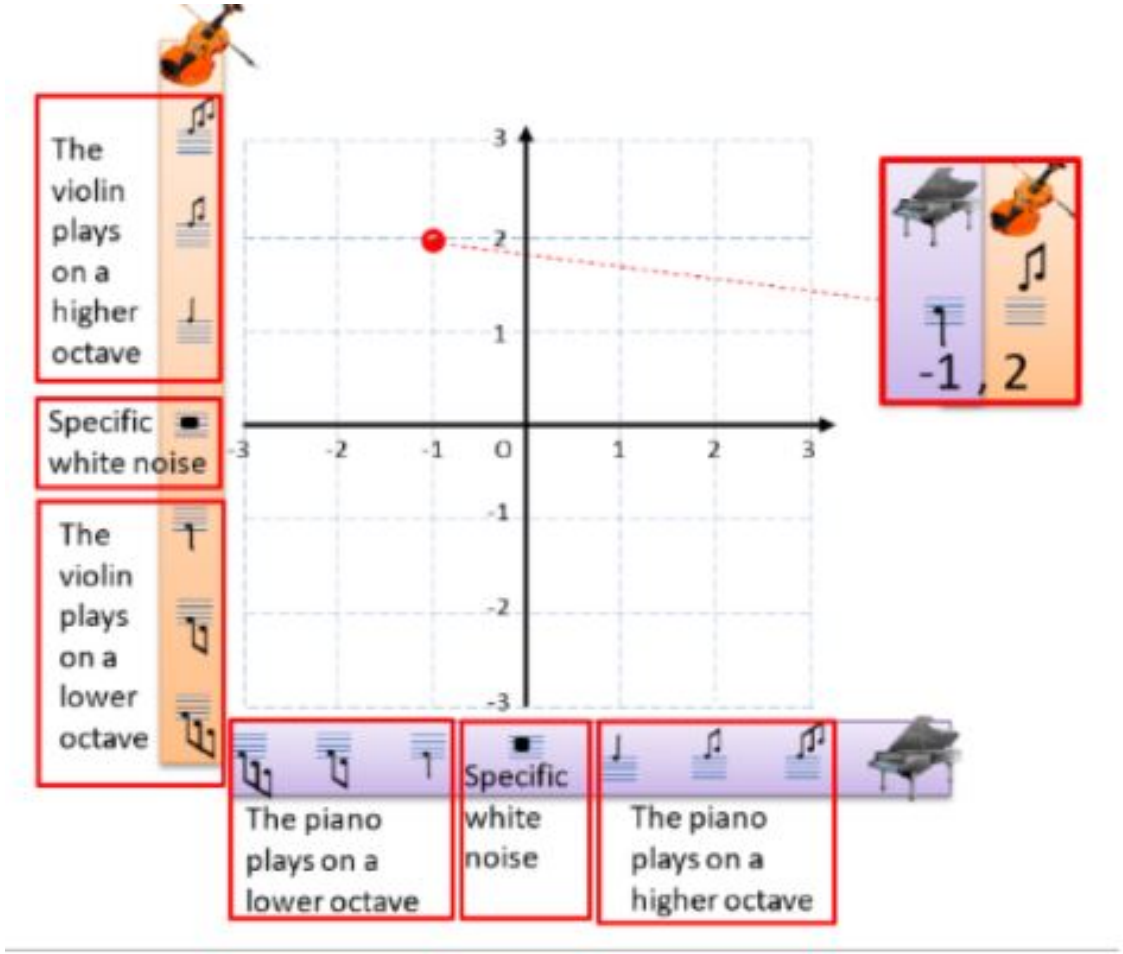
AngleShapes Game sonification model



Based on psychophysics association between pitch and shape, well studied in synesthesia literature (Rigas and Alty, 2005), (Lawrence, 1975), (Mondloch, Maurer, 2004)

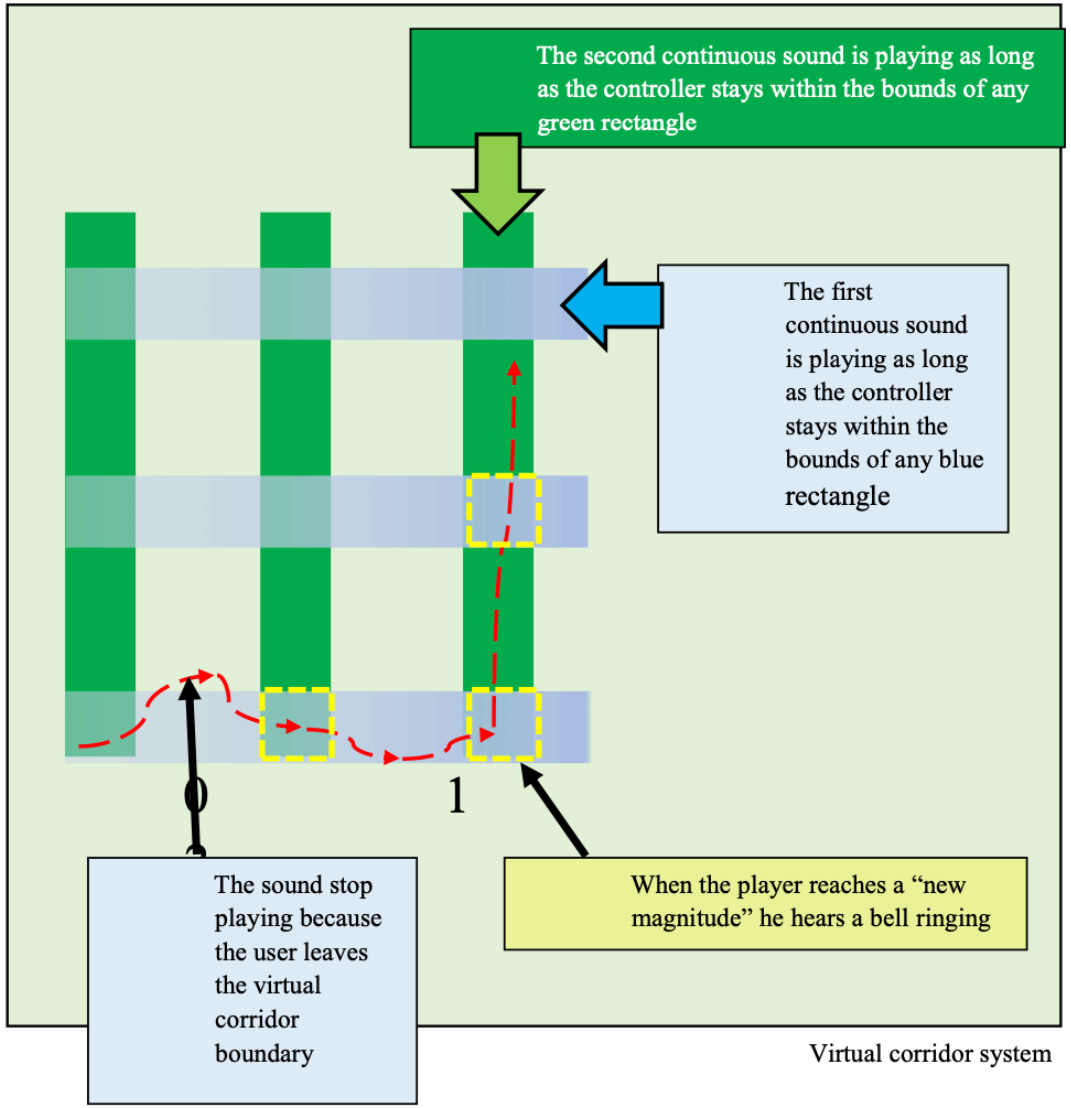
CartesianGarden sonification model





Double model, suitable both from younger and/or blind children (the ***narrative*** one) and from older ones (the music map one)

CartesianGarden sonification model



AngleShapes Game Low-vision adaptation

CartesianGarden: sonification model for visually impaired children

video

video

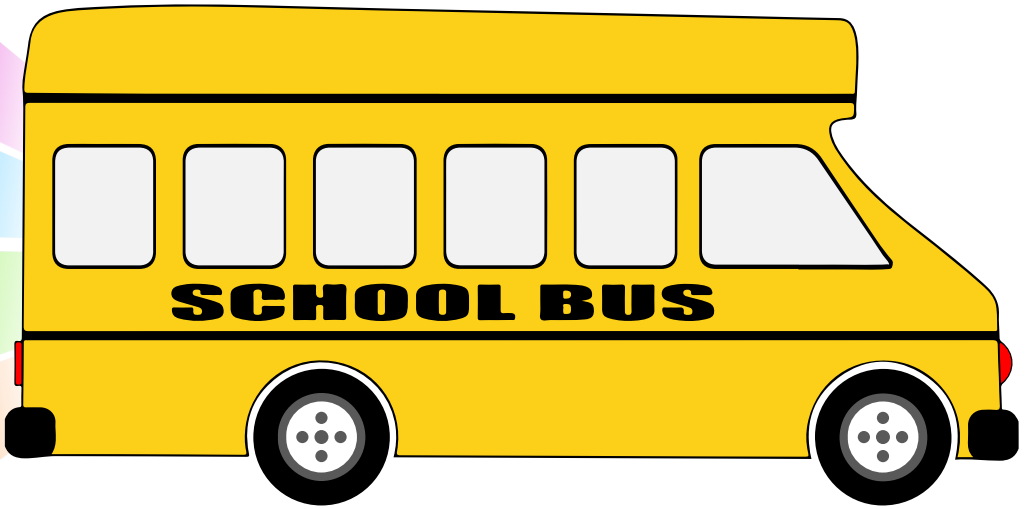
What cognitive states should we monitor in learning tasks?

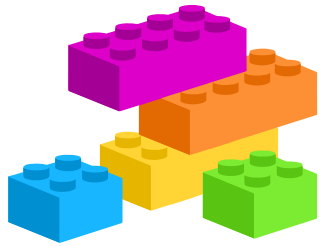
How non-verbal communication can be used in automatic affective detection?

What cognitive states literature highlight to be important in learning task?

What guidelines for affective computing we can use to develop adaptive educational serious-games?

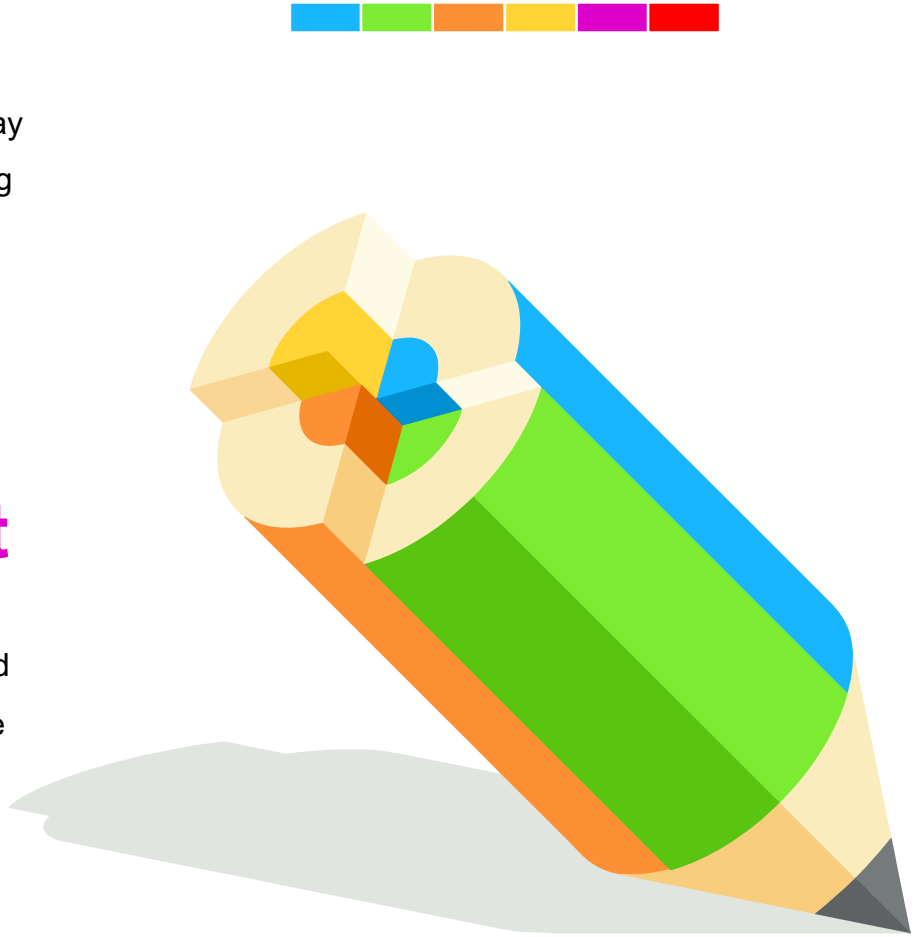
How HCI research literature efficiently address its design to sensory impaired learners?





Reflective thinking

is integral to learning (Kolb, 2015), (Mezirow, 1991), (Rodgers, 2002), (Dewey 1933) and may be necessary for mathematical problem solving (Navarro, Aguilar, Alcalde, & Howell, 1999).



Confidence

Its importance in learning has been proven and linked with the amount of effort and the level of persistence that a learner will put into the completion of the learning task in the face of barriers (A. Bandura. 1977).

Engagement

It is something strictly related to motivation and has a great power on participation and positive outcomes in learning (Fredricks, Blumenfeld & Paris, 2004).

We identified different sensors-based and motion-based features, but for the use in our full-body platform we found measurements of precision of movements and trajectories, velocity, hesitance, number of trials, face gaze, body posture, energy of movements as the most representative.

Non-verbal behavior of visually impaired children

To which extent visual impairment may affect the development of nonverbal communication patterns in visually impaired children?

We performed a double check annotation of video segments, looking for engagement, self-confidence and what non-verbal cues where used to recognize those states

Movement quality			Posture			Gesture		
Id	*Cues*	*%*	*Id*	*Cues*	*%*	*Id*	*Cues*	*%*
1	Focused, direct movement	34.44	10	Gaze down	38.99	21	Exp. of positive emotions (e.g. laughter)	18.33
2	Jerky movement	25.00	11	Tendency to act	25.00	22	Nervous smile or laughter	13.99
3	Hesitating movement	22.78	12	Listening predisposition	25.00	12	Open mouth	10.00
4	Fluid movement	21.11	13	Body as a reference point	20.00	21	Nodding during tasks resolution	7.88
5	Impulsive movement	20.00	14	Gaze contact with the interlocutor	18.33	25	Grabbing clothes	7.88
6	Inhibited movement	17.22	15	Withdraw from action	16.77	26	Rocking	7.88
7	Not goal-oriented movement	16.77	16	Outward-facing gaze	13.99	27	Lips biting	6.77
8	Slow movement	15.00	17	A loss of posture alignment	13.33	28	Deictic gestures	5.00
9	Misalignment		18	A loss of balance		29	Hands kept together	5.00
	of different body planes	11.11		(feet support instability)	13.32	30	Hands hold behind back	4.44
			19	Posture openness	8.89	31	Touching face or mouth	0
			20	Legs are moved while body is still	7.78			

Preliminary results show that cues as gaze still have a relevant weigh in considering engagement and self-confidence.

Some annotated behaviours are *continuous*, that can be present in both the states, co-occuring with other cues.

While other features are binary behaviors.

Usability evaluation

How to evaluate the efficacy of multimodal learning games, considering both typical and sensory impaired children?

A new evaluation checklist

GAMEPLAY

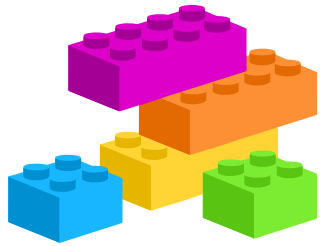
1. Check if the player has *difficulties* to:	Did it happen?	In which task?	Severity
1.1 Learn how to play	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.2 Learn how to use the controls	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.3 Handle the controls	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.4 Understand the game goals	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.5 Play without mediation	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.6 Play according to the information provided by the game	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.7 Accomplish the game tasks	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.8 Move through the virtual game environment	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.9 Rotate in the virtual game environment	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.10 Recognize different scenarios in the game	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.11 Distinguish the different characters in the game	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.12 Distinguish the distinct roles in the game	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
Check if the player demonstrates to *feel*:			
1.13 Bored, or uninterested while playing	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
1.14 Annoyed by any of the game controls	☐YES ☐NO		☐1 ☐2 ☐3 ☐4

ACOUSTICS

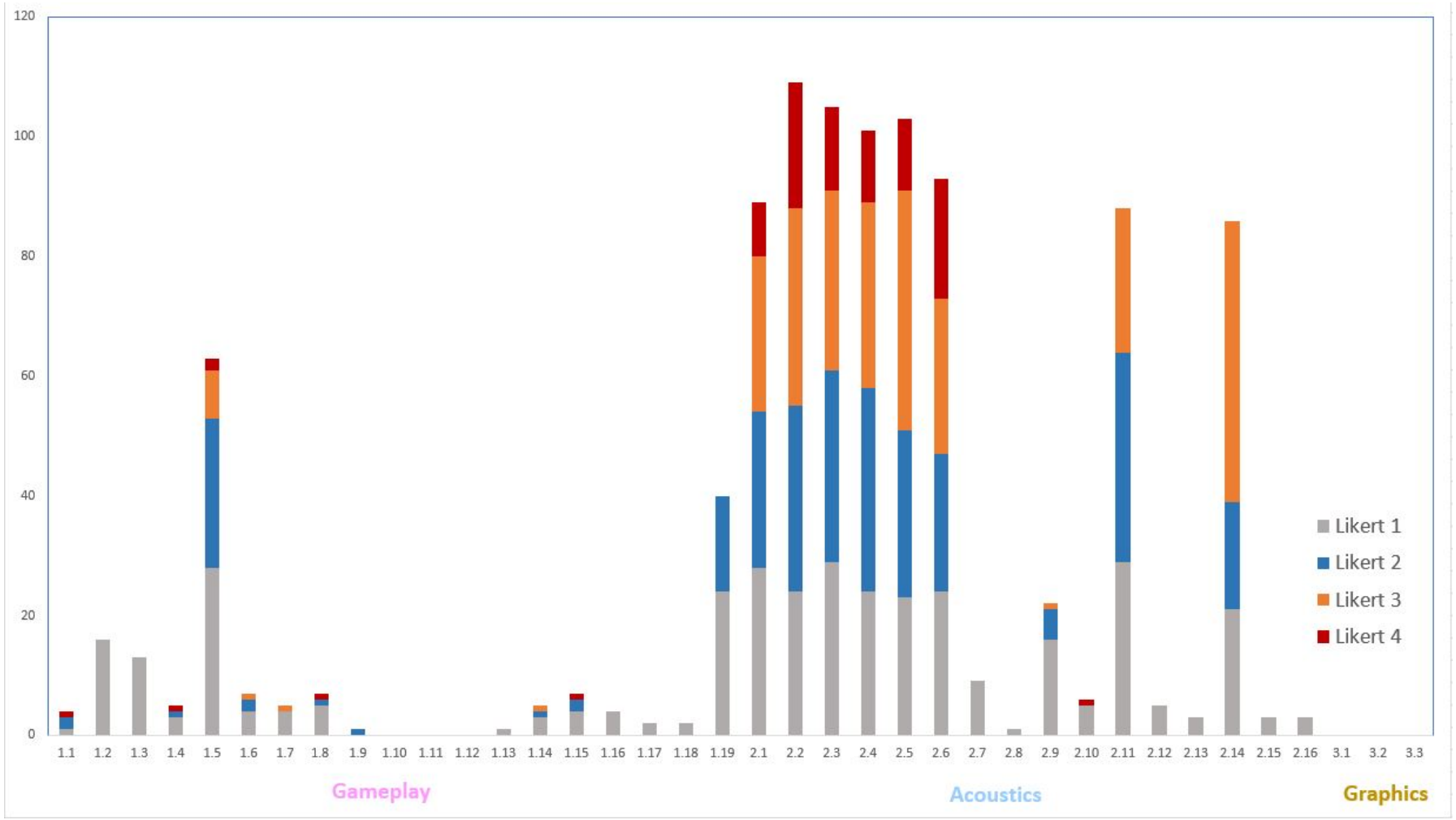
2. Check if the player has *difficulties* to:	Did it happen?	In which task?	Severity
2.1 Hear the game sounds	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
2.2 Identify a specific sound	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
2.3 Recognize a specific sound	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
2.4 Understand the information conveyed by a sound	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
2.5 Realize that a specific sound is related to a specific action in the game	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
2.6 Associate the game sounds with his prior knowledge	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
2.7 Associate the game sounds with the right objects or actions in the game	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
2.8 Understand information about orientation and location in the game environment	☐YES ☐NO		☐1 ☐2 ☐3 ☐4
2.9 Identify the purpose a specific audio feedback			☐1 ☐2 ☐3 ☐4
Check if the *audible feedback*:			
2.10 Are sufficient to the execution of the game activities	☐YES ☐NO		☐1 ☐2 ☐3 ☐4

Basing our work on CLUE checklist (Ticianne, D. et al., 2018), we developed a new evaluation protocol, intended to be used by external observers during user interaction, that suits full-body multisensory serious-game for both typical and sensory impaired users.

https://tinyurl.com/sxof6mf

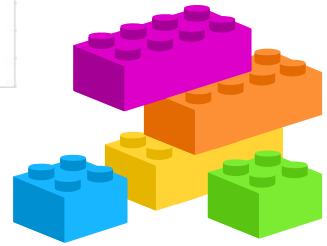


AngleShapes Game Usability

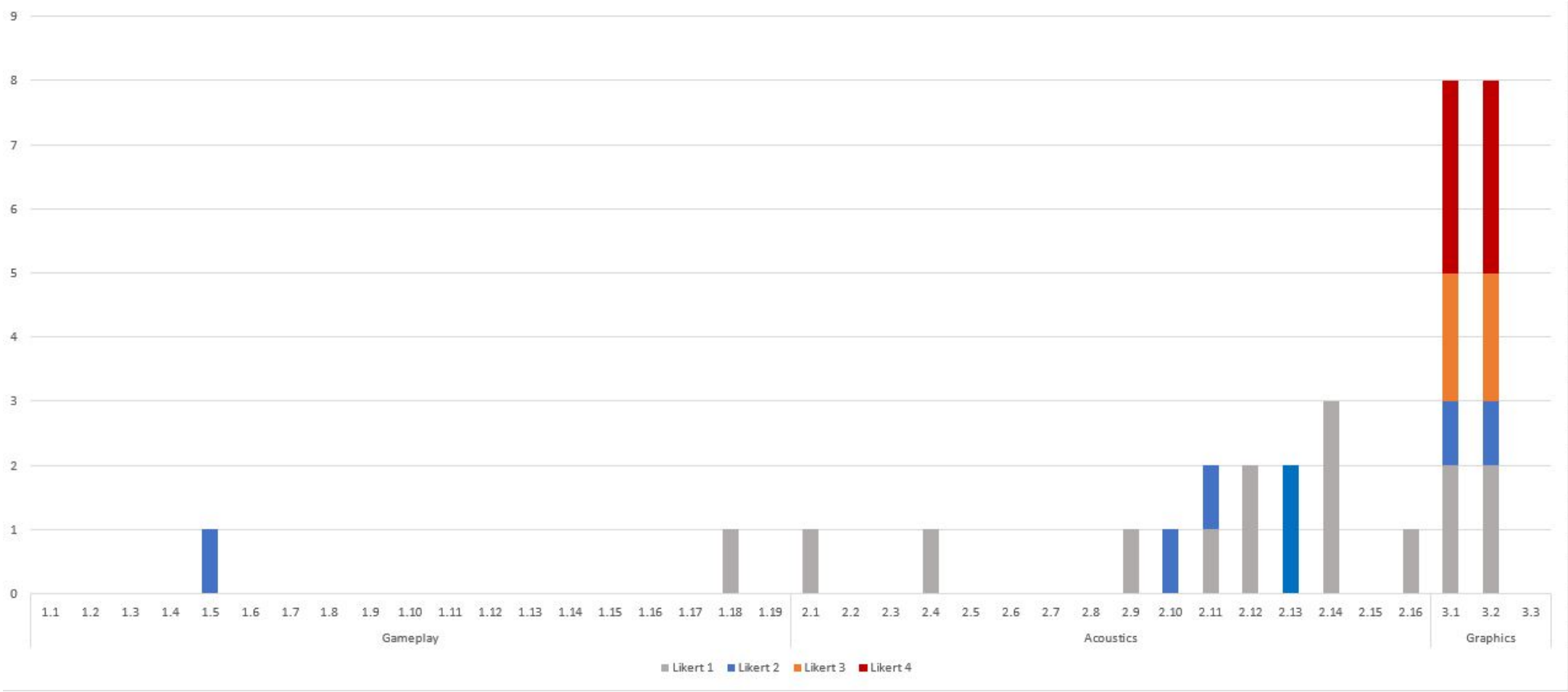


Typically developed children

N=111, age mean=8.66

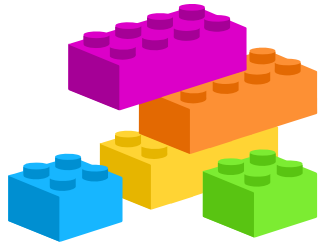


AngleShapes Game Usability

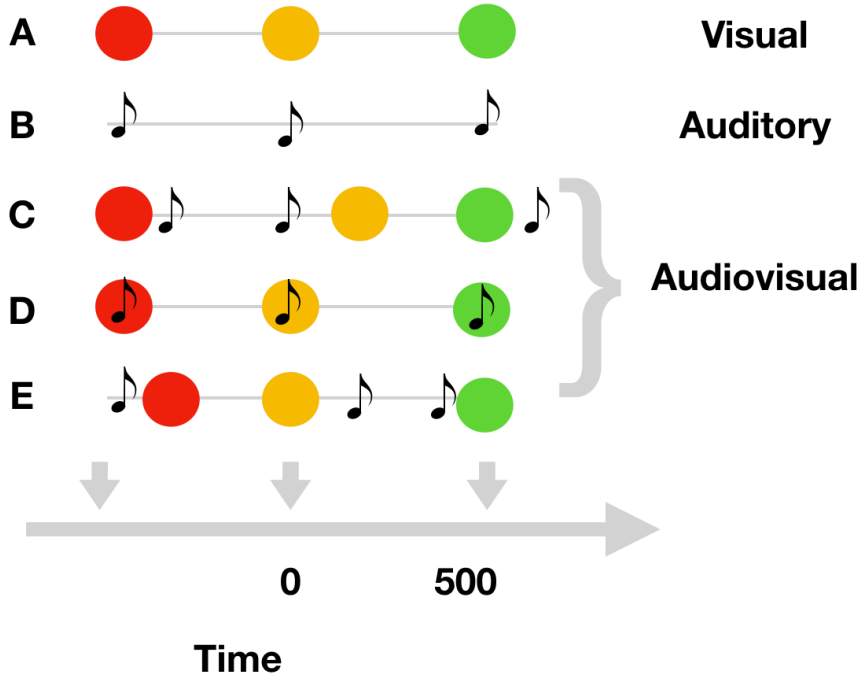


V.I. children

N=3 age mean=10

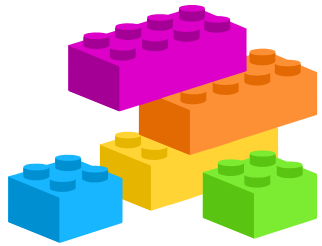


Dyslexia screening and training



The SynchroHorse Race

An Android app to enhance temporal and rhytmic perception processing for dyslexic primary school children



TELMI

TECHNOLOGY ENHANCED LEARNING OF MUSICAL INSTRUMENT PERFORMANCE

video

A new pedagogy model, based on enhancing embodied understanding and proprioceptive feedback of violin students.

My research on TELMI

Understanding motor-related features effectively involved in learning and practice music.

Analysis of movement features for muscular tension control

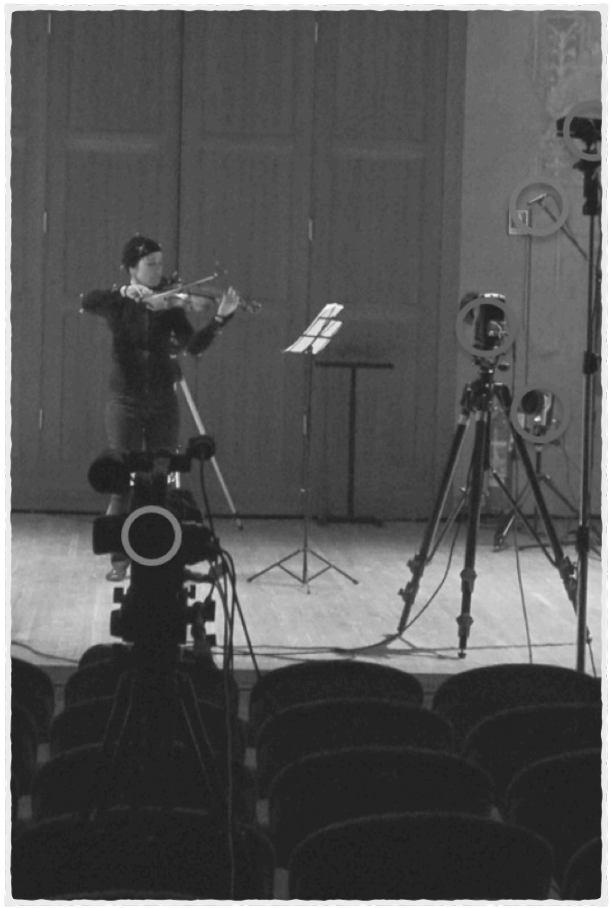
Multimodal archive of violin performances

Real-time feedback interface

Analysis of movement features for bowing control and automated teacher/student classification

User evaluation

Multimodal TELMI Archive

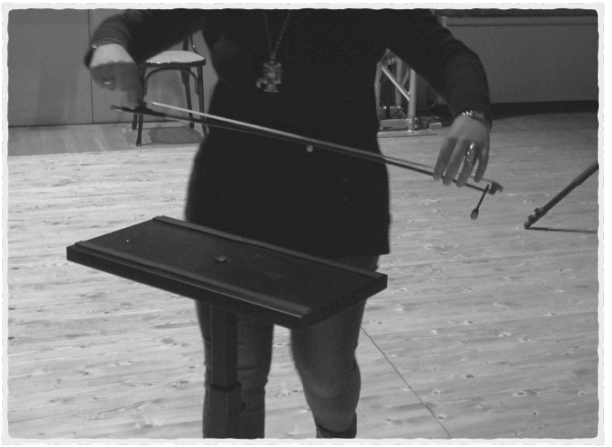


4 RCM violin performance

1 Teacher

3 Students

41 (21) Exercises

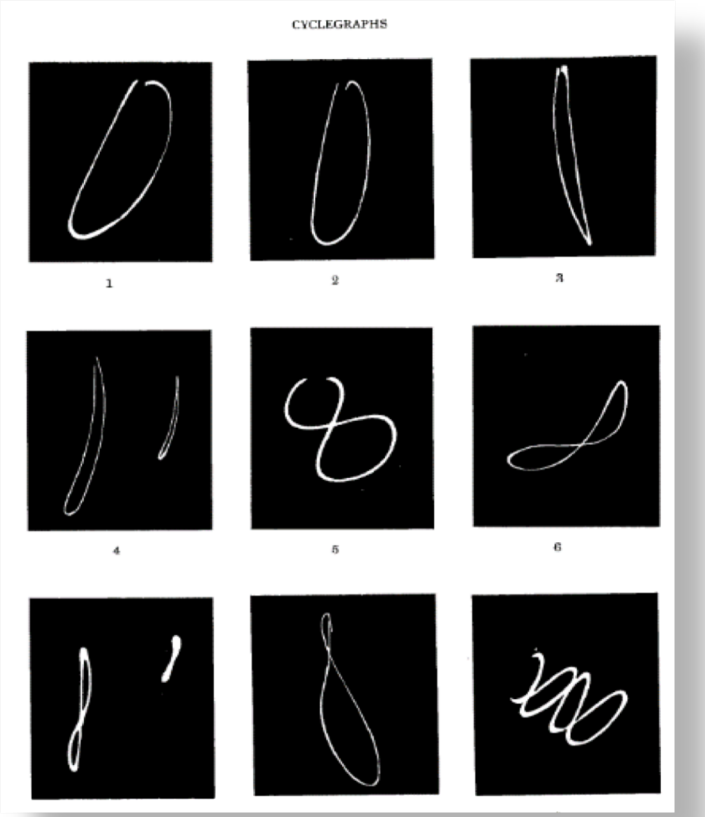


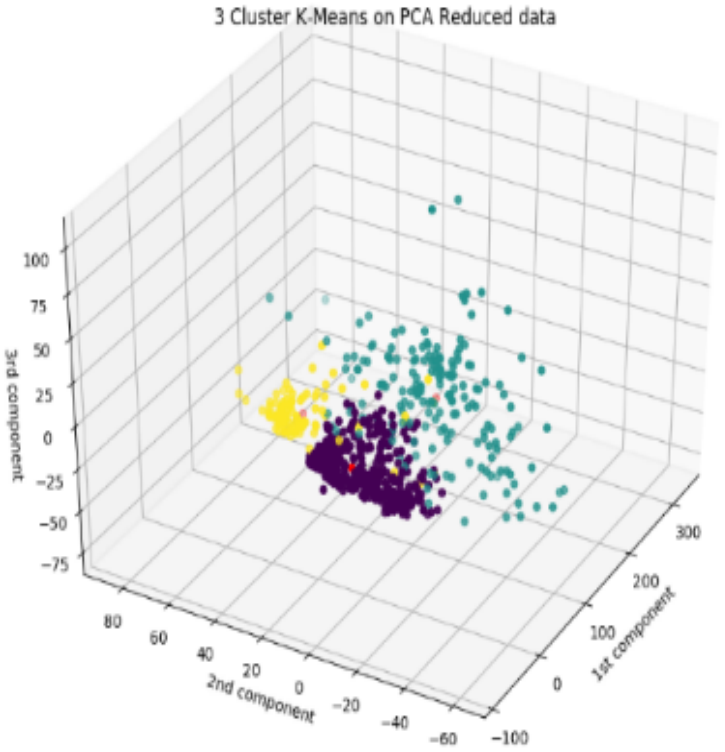
Volpe, G., Kolykhalova, K., Volta, E., Ghisio, S., Waddell, G., Alborno, P., Piana, S., Canepa, C., and Ramirez-Melendez, R. 2017. A multimodal corpus for technology-enhanced learning of violin playing. In Proceedings of the 12th Biannual Conference of the Italian SIGCHI Chapter (CHItaly '17). ACM, New York, NY, USA, Article 25, 5 pages. DOI: https://doi.org/10.1145/3125571.3125588

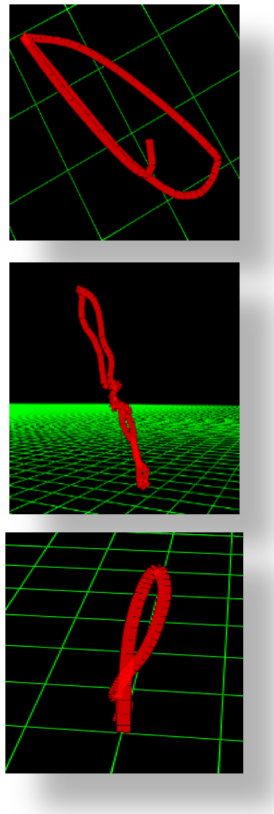
A solitary training

- Traditional music education is mostly based on a master-apprentice relationship, with long period of self-study for the students.
- Traditional teaching methods of the biomechanics components of musical performance may be based on subjective perception.
- Musical performance shares many characteristics, including health risks, in common with other skill-oriented activities, as sports.

Bowing techniques



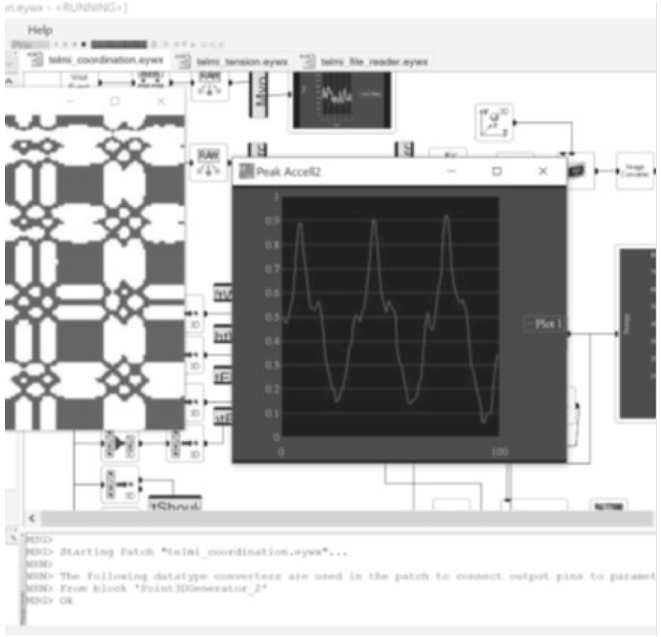


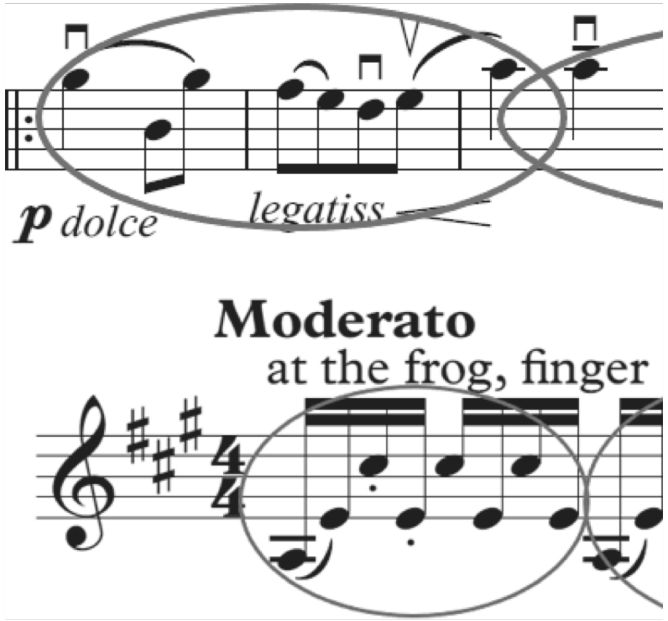


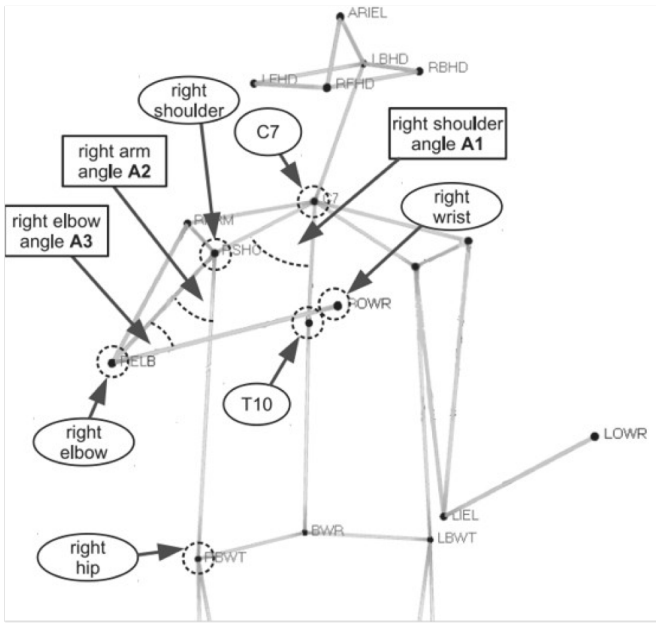
Volta, Alborno, Volpe, **Informing bowing and violin learning using movement analysis and machine learning** in Proceedings of 10th International Workshop on Machine Learning and Music, 2017

Students' performance and safety

A preliminary study

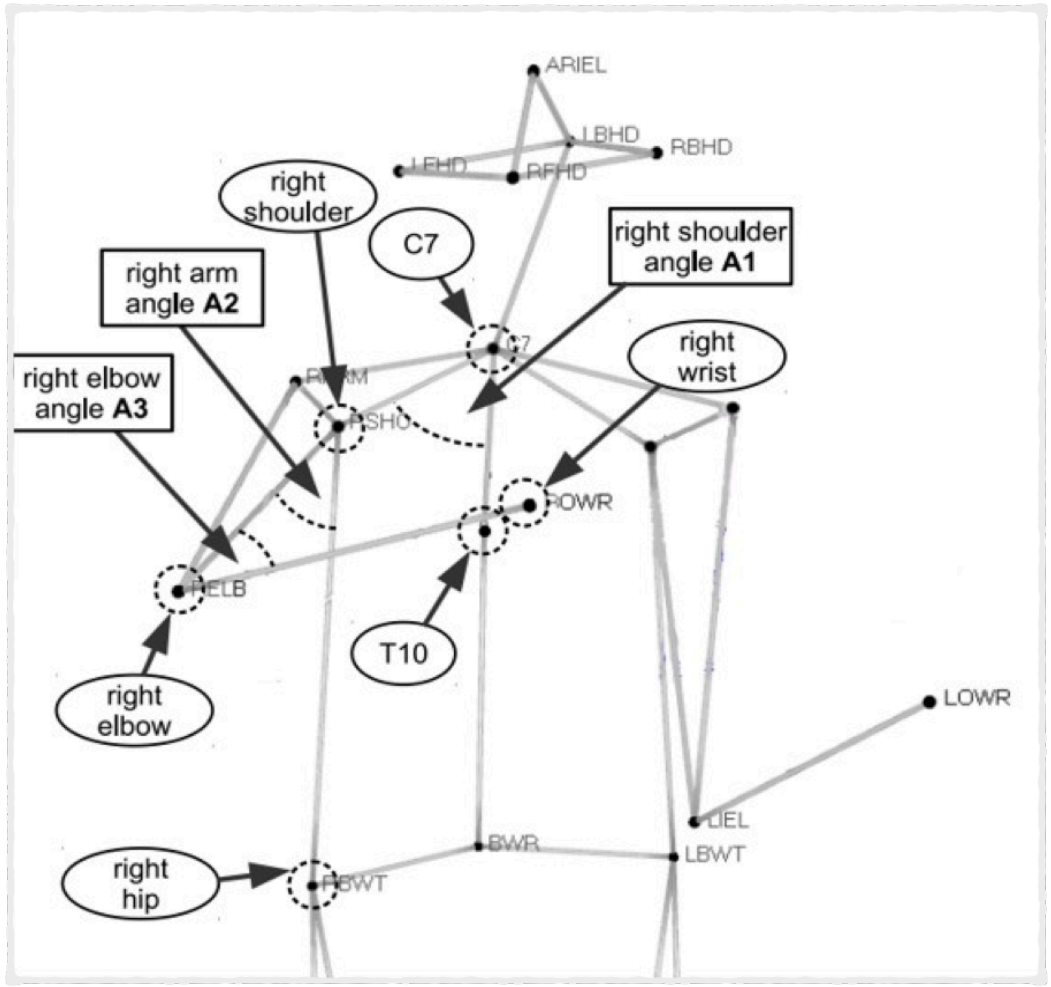






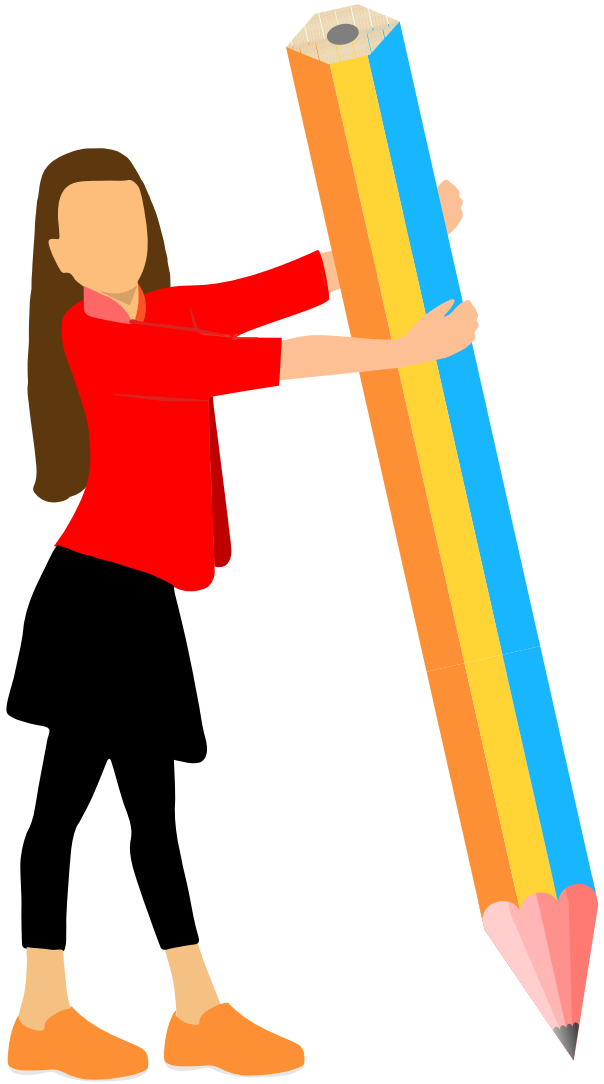
Volta, E., Mancini, M., Varni, G., & Volpe, G. (2018, June). Automatically measuring biomechanical skills of violin performance: an exploratory study. In Proceedings of the 5th International Conference on Movement and Computing (p. 16). ACM.

Body features analysis…



- Shoulders' dynamics
- Shoulders' position
- Upper body dynamics

… and human evaluation



01

Expert evaluation

We asked to three experts musicians to evaluate violin skills, through a questionnaire, using an interactive slider.

02

Internal consistency

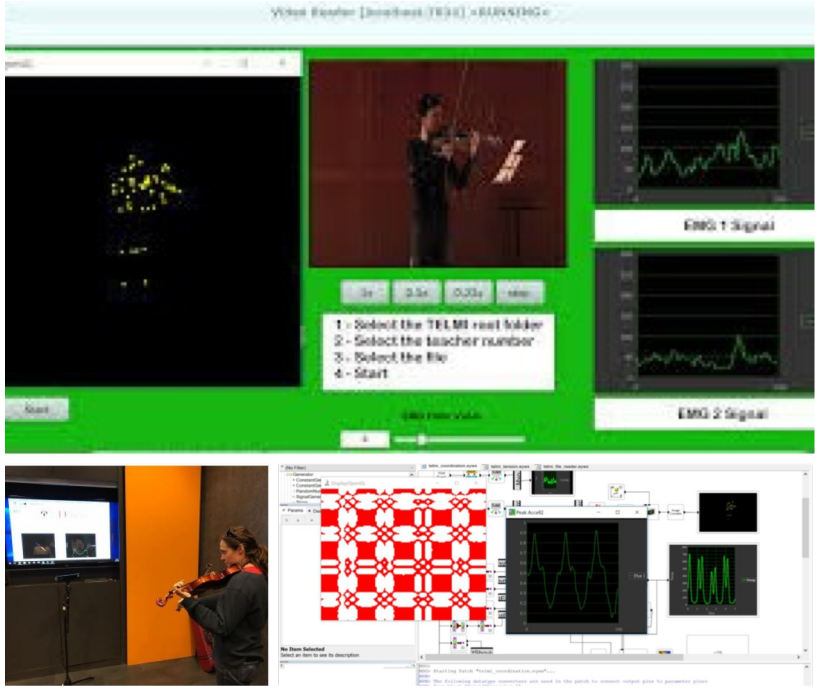
Internal consistency was assessed through Cronbach's.

Next step

We planned to extend the analysis to audio features, e.g. timbre, pitch and tonality.

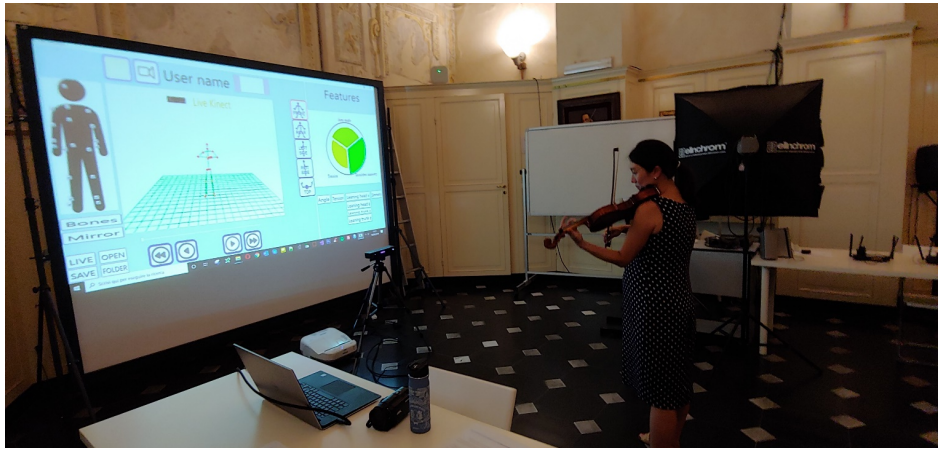
The analysis of both motion and audio features for muscular tension is ongoing.

Real-time feedback interface



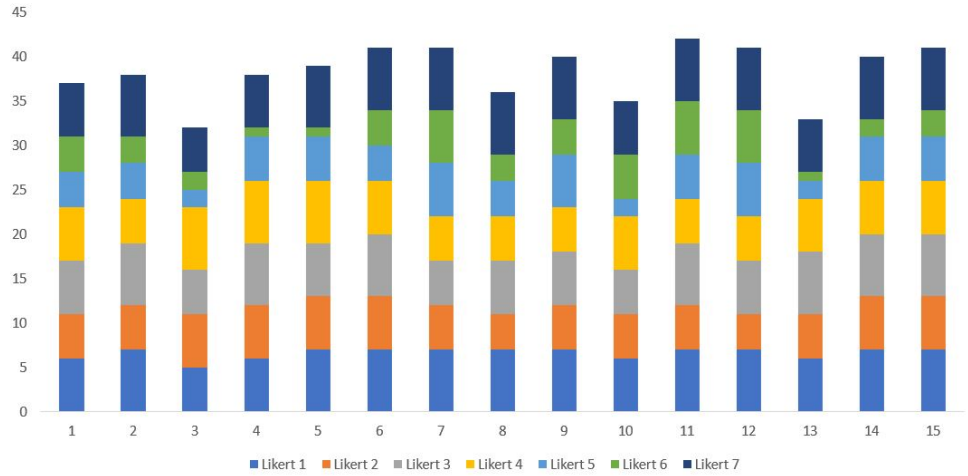
With the RCM of London, we performed a series of iterative design meetings to understand what kind of visual information can efficiently improved proprioceptive and embodied posture understanding while playing.

The final platform, SkyMotion, was evaluated by 8 violinists, through a series of semi-structured interviews.



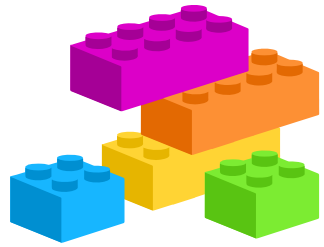
SkyMotion Evaluation

No.	Question	Expert Likert evaluation						
	To what degree did this feedback…	**Exp.1**	**Exp.2**	**Exp.3**	**Exp.4**	**Exp.5**	**Exp.6**	**Exp.7**
1	…help you learn more quickly?	6	5	6	6	4	4	6
2	… improve your performance?	7	5	7	5	4	3	7
3	… increase your productivity?	5	6	5	7	2	2	5
4	… increase the effectiveness of your practice?	6	6	7	7	5	1	6
5	… make practicing easier?	7	6	6	7	5	1	7
	To what degree was this feedback…							
6	… useful?	7	6	7	6	4	4	7
7	… easy to learn to operate?	7	5	5	5	6	6	7
8	… something that did what you wanted it to do?	7	4	6	5	4	3	7
9	… clear and understandable?	7	5	6	5	6	4	7
10	… flexible?	6	5	5	6	2	5	6
11	… easy to become skilled at?	7	5	7	5	5	6	7
12	… easy to use?	7	4	6	5	6	6	7
13	… accurate?	6	5	7	6	2	1	6
14	… something you would use again?	7	6	7	6	5	2	7
15	… something you would recommend to others?	7	6	7	6	5	3	7



"I would like to use SkyMotion with my students to help them understand the importance of working on own body before working on music performance."

"It can be very useful for students at home, since after hours of practice they are tired and easily lose their correct posture and its naturalness, increasing muscular tensions."



THANK YOU

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https://www.researchgate.net/profile/Erica_Volta