PLAYER-CENTRIC ADAPTATION IN VIDEO GAMES FOR EDUCATION

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Professor Harald Hepner Conferred a Doctor Honoris Causa Degree by Sofia University

At Aula magna of Sofia University "St Kliment Ohridski" a solemn ceremony was held to confer a Doctor honoris causa degree to Professor Harald Hepner from Carl Franz University (Graz, Austria).

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Education

- Bachelor's Degree Programmes
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Faculty of Mathematics and Informatics

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- **Technology enhanced learning**: models, adaptability, authoring/instructional/delivery platforms and interoperability
- **Content collaboration and access to cultural heritage** - MECITV: Media Collaboration for Interactive TV; semantic technologies for cultural heritage
- **Software services, quality and cloud**
- **Video games**:
  - MMORPG (SHIVER project of MyAlert S.L., Spain);
  - Creating virtual business models, tools and environments (FP6 PRIME: Providing Real Integration in Multi-disciplinary Environments);
  - Models of board games for education for ADOPTA: ADaptive technOlogy-enhanced eduTainment platform for building edutainment
  - H2020 RAGE (Realising an Applied Gaming Eco-system)
  - ADAPTIMES (ADAPTIve player-centric serious video gaMES) - with Brainstorm Multimedia, Spain

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Agenda

- Introduction
- Problems of player-centric adaptation in video games
- The ADAPTIMES player model
- Dynamic adaptation process using player performance, affect and playing styles
- Case study 1 - the “Rush for Gold” emotionally adaptive game
- Case study 2 – adaptive educational maze/quiz/zoom games
- Conclusions and future works

Player-centric adaptation

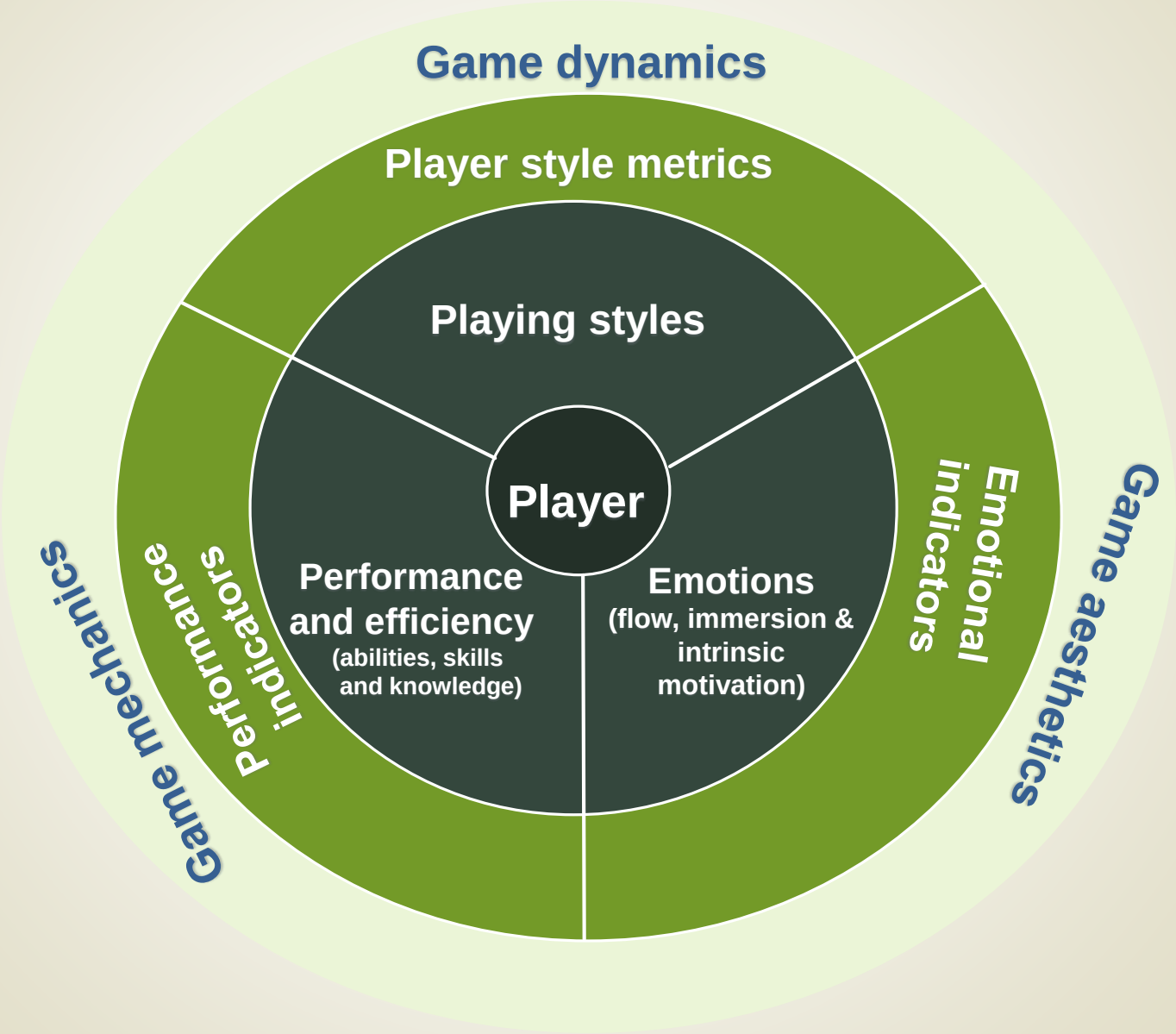
Player-centric adaptation in video games needs to answer some questions:

- **Who** – player character structural and behavioral changes => requires player modelling
- **How** – how adaptation will be realized => requires adaptive loop design
- **What** – which game features can be adapted => requires adaptive gameplay design
- **Why** – advantages of game adaptation => requires analysis of outcomes in playability and learning results

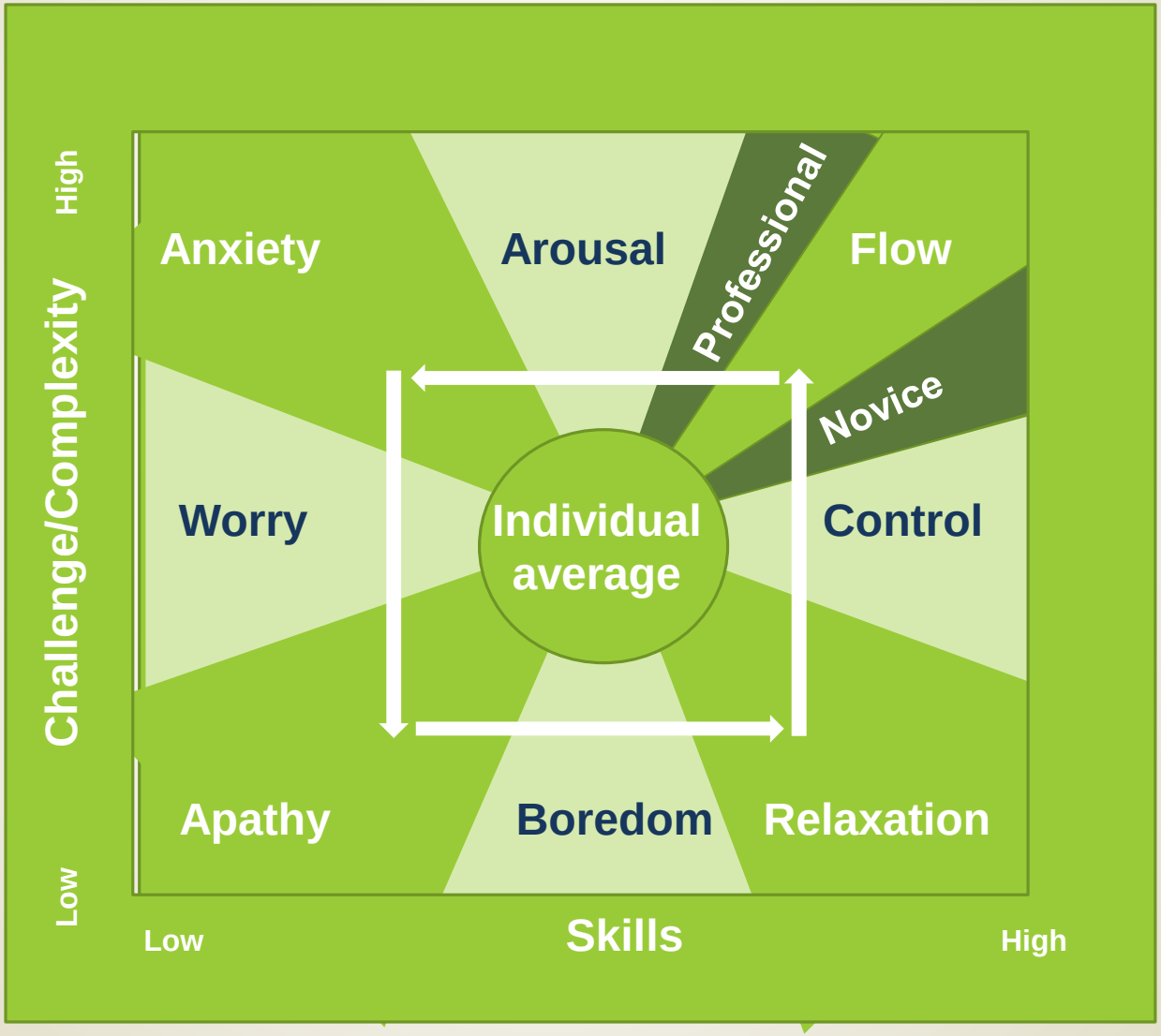
The ADAPTIMES FP7 project

- ADAPTIve player-centric serious video gaMES
- ADAPTIMES aims at investigating how
  - cognitive abilities (the ***cognitive*** part),
  - psycho-emotional status (the ***affective*** part) and
  - playing style (the ***conative*** part – that of "desire, volition, and striving")
- can be used in a holistic approach for efficient and effective player-centric adaptation

ADAPTIMES Adaptation Model



Flow mental state as function of challenge and player's ability/skills (Csikszentmihalyi, 1997)

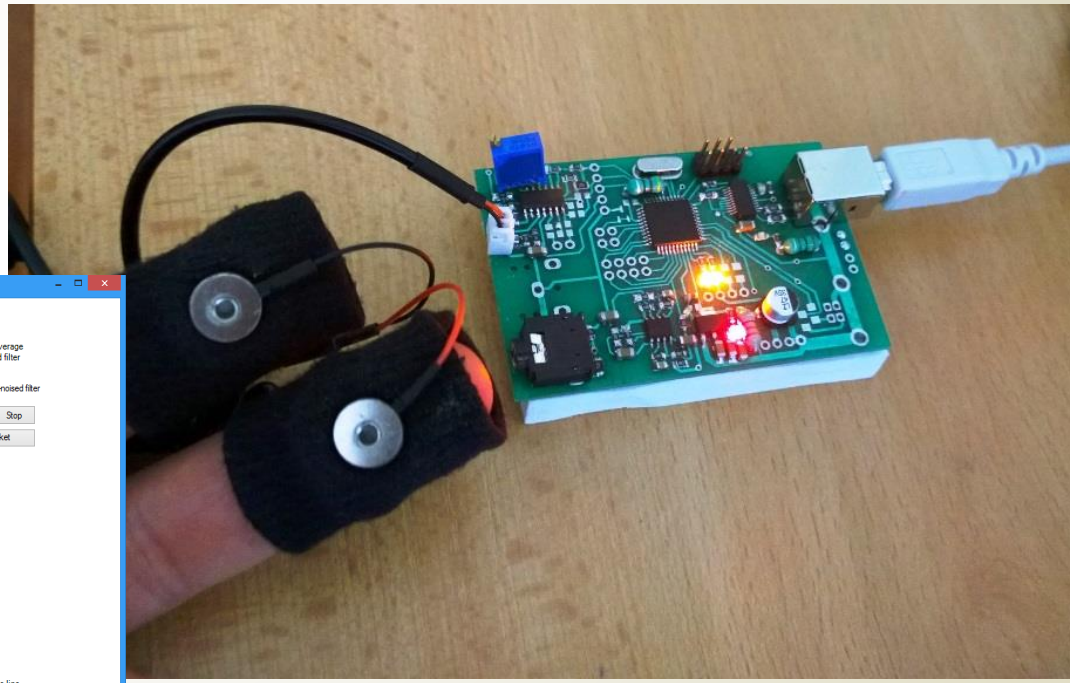


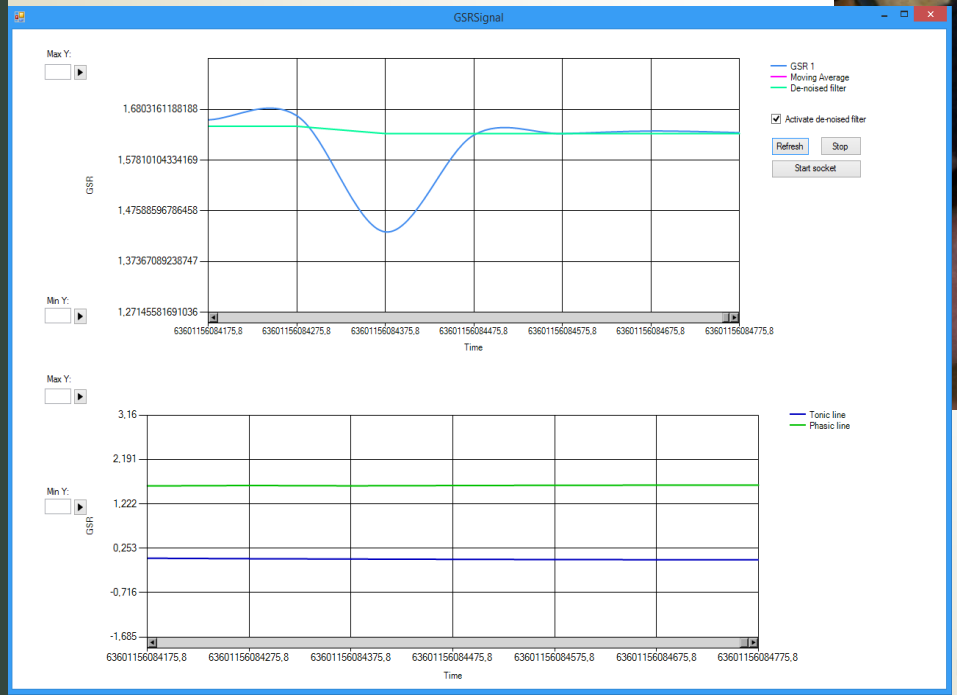
Measuring process

- Measuring player's ***performance*** – by tracking player's results, incl. time, task difficulties and efficiency
- Measuring ***playing styles*** – based on tracking specific gaming metrics describing player's style of playing
- Measuring player's ***affect*** (emotions and arousal):
  - By means of analysis of psychophysiology signals (arousal)
  - By means of visual expressions analysis (emotional states)

Affect inferred by psychophysiology signals

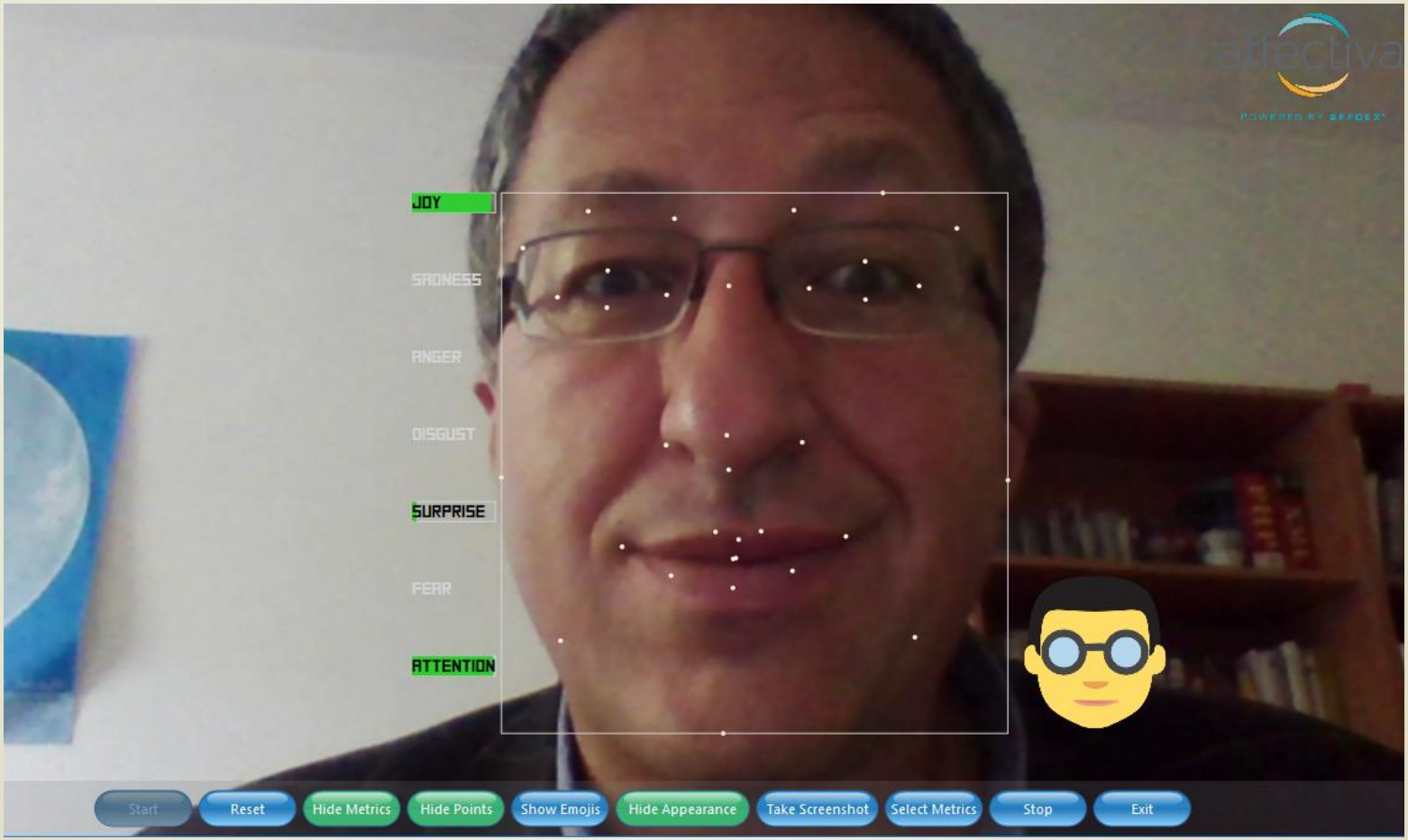
- EDA (Electro-Dermal Activity)
- Custom EDA meter – custom hardware device and software (H2020 RAGE asset developed by SU)



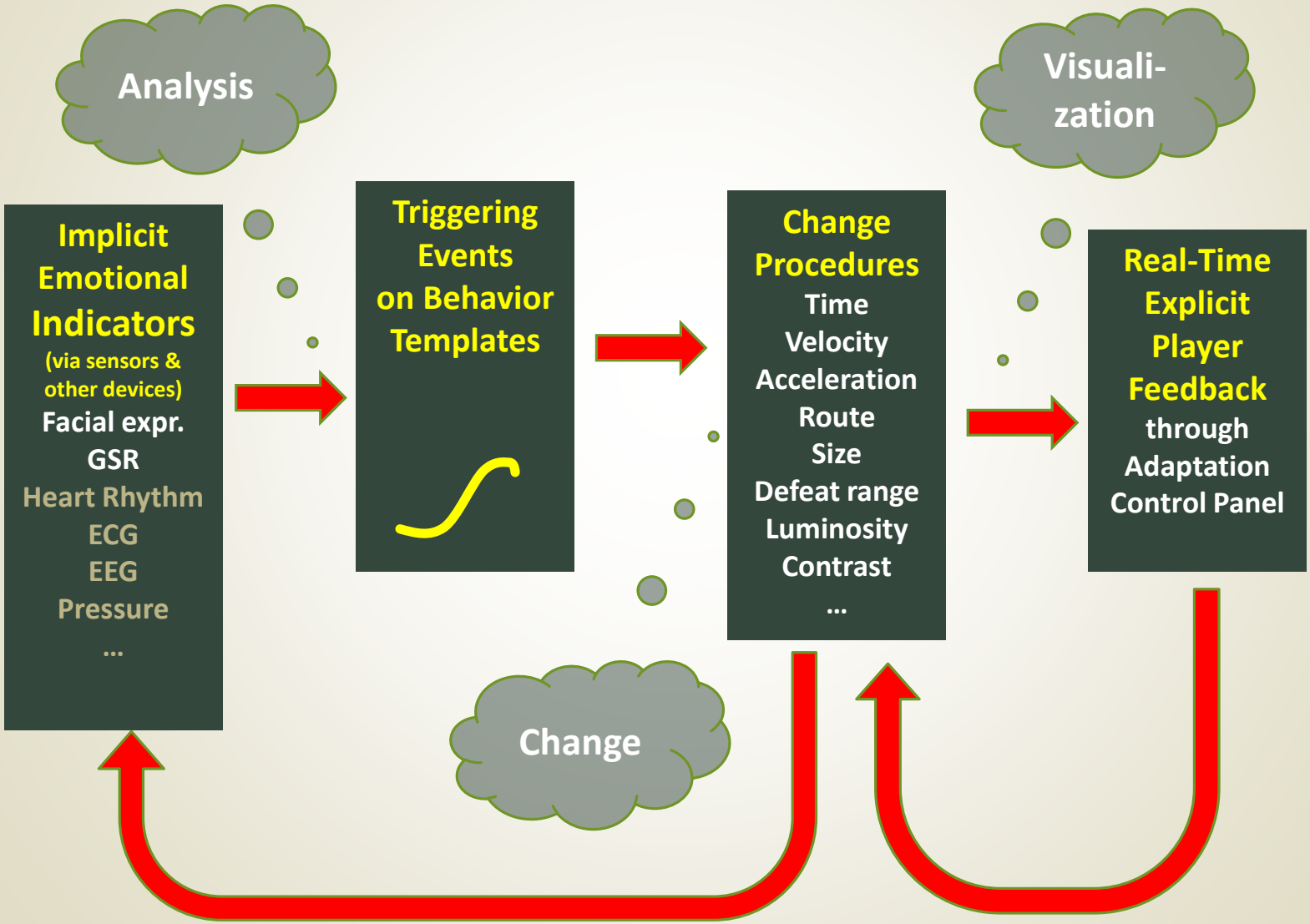


Emotions inferred by visual expressions analysis

- Custom emotion recognizer using Affectiva SDK
- Recognizes: *sadness, disgust, anger, surprise, fear, joy*; *engagement, attention (fixation), eye closures (saccades)*

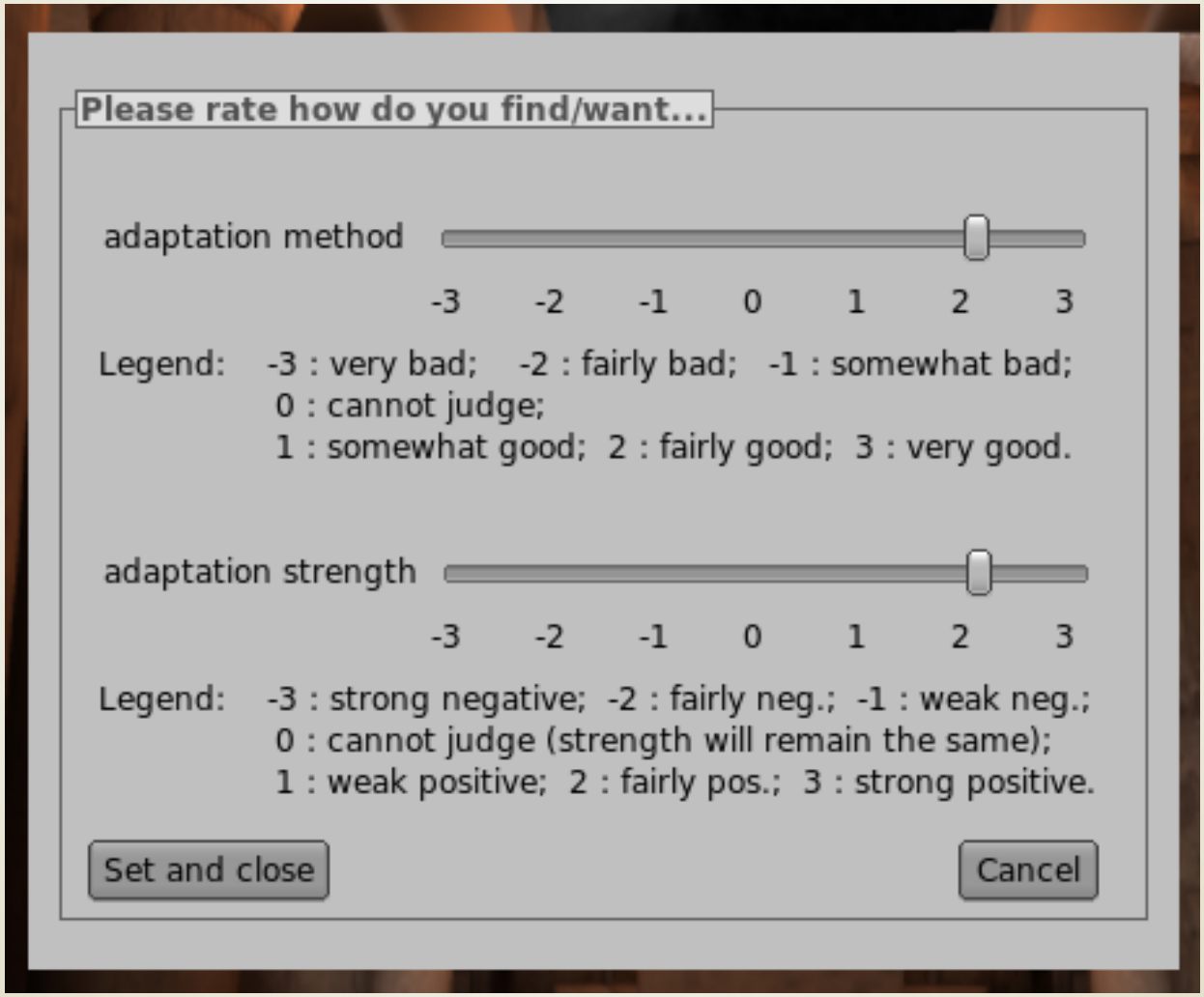


Workflow of emotion-based game *dynamic* adaptation control



In-Game Explicit Player Feedback

- using a built-in Adaptation Control Panel



Playing style vs learning style

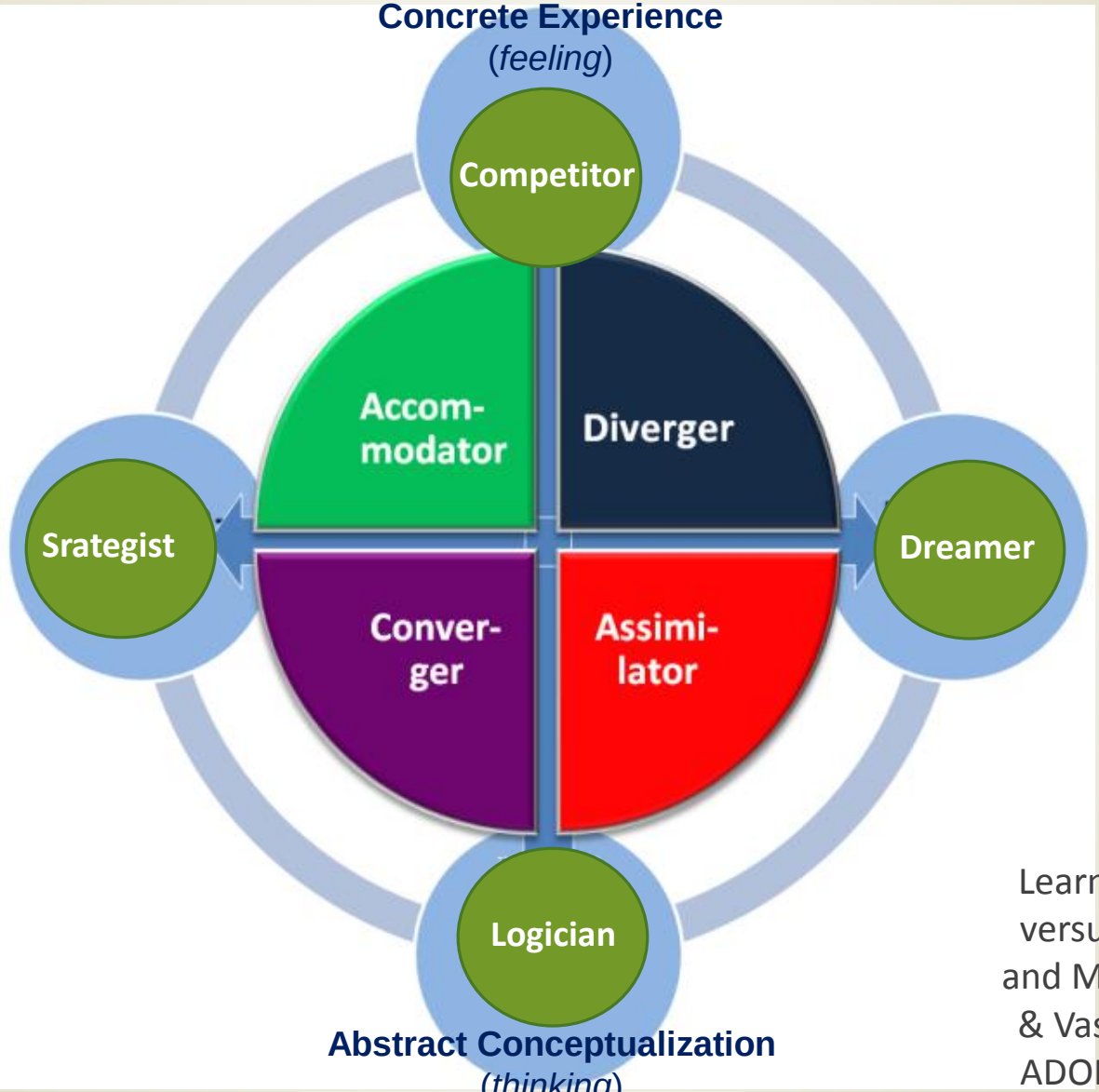
- **Playing style** - persistent traits of the player, whereas defined play styles as treating "motivations as a more temporary state, with an implication that players may adopt different play styles in different games or at different times".

  (Magerko et al., 2008)

- **Learning style** – "characteristic cognitive, effective, and psychosocial behaviors that serve as relatively stable indicators of how learners perceive, interact with, and respond to the learning environment".

  (Curry, 1981)

Styles based on Kolb learning process



Learning styles of Kolb versus styles of Honey and Mumford (Bontchev & Vassileva, 2012) and ADOPTA playing styles (Aleksieva et al, 2011)

Playing style models

Relationships between Honey and Mumford (1982) learning styles and playing styles of ADOPTA (Aleksieva et al., 2011) and Bartle (1996)

Honey and Mumford	Learns/plays by:	ADOPTA	Bartle
Activist	Hand–eye coordination, planning and strategizing, problem-solving, teamwork and the ability to think quickly	**Competitor**	**Killer**
Theorist	Logically entering problems step-by-step, with spatial awareness and verbal & numeracy skills	**Logician**	**Achiever**
Pragmatist	Planning, decision-making, testing hypotheses, strategic thinking, management skills	**Strategist**	**Explorer**
Reflector	Observing and watching reflectively	**Dreamer**	**Socializer**

Player style measurement 1/2

- **Explicitly** - though self-report
  - A 40 items questionnaire for measuring Competitor, Discoverer (Dreamer), Logician and Strategist style of playing
  - Experimented together with the 40 items questionnaire for measuring Honey and Mumford learning styles

Playing style	Competitor	Discoverer	Logician	Strategist
Cronbach's alpha	0,63606	0,80414	0,78935	0,70201
N	260			

Correlations Playing style/ Learning style	Competitor /Activist	Discoverer/ Reflector	Logician/ Theorist	Strategist/ Pragmatist
r	0,75562	0,71113	0,83883	0,70487
p-value	0,00000	0,00000	0,00000	0,00003
N	152			

Rest-retest reliability of the questioner

Playing style	Time period	r	p (two-tailed)	N
Competitor	DEC/FEB	0,9809948	0,0000	34
	FEB/JUN	0,9182861	0,0000	
Discoverer	DEC/FEB	0,9403670	0,0000	
	FEB/JUN	0,7770357	0,0001	
Logician	DEC/FEB	0,8093530	0,0000	
	FEB/JUN	0,5762087	0,0123	
Strategist	DEC/FEB	0,9692993	0,0000	
	FEB/JUN	0,5133127	0,0294	

Player style measurement 2/2

- **Implicitly** - during game time of playing specific mini-game
  - Based on player's metrics for specific game tasks including performance (result), efficiency (result/effort), task difficulty and play time
  - Linear regression coefficients ($k_{C1\div4}$, $k_{D1\div4}$, $k_{S1\div4}$, $k_{S1\div6}$,) determined by:
    - Qualitative study (structured interviews with gamers)
    - Adjusted by the least squares method (LSM)
  - Calculation incorporated into an adaptive action video game

Style calculation

Effect (result) normalised for one bullion: EFF_{norm}

Average efficiency normalised for one bullion: AE_{norm}

Average difficulty normalised for one bullion: AD_{norm}

- Competitor (shooter):
  $R_C = k_{C1} * EFF_{Cnorm} + k_{C2} * AE_{Cnorm} + k_{C2} * AD_{Cnorm} + k_{C4}$
- Dreamer:
  $R_D = k_{D1} * EFF_{Dnorm} + k_{D2} * AE_{Dnorm} + k_{D3} * AD_{Dnorm} + k_{D4}$
- Logician:
  $R_L = k_{L1} * EFF_{Lnorm} + k_{L2} * AE_{Lnorm} + k_{L3} * AD_{Lnorm} + k_{L4}$
- Strategist:
  $R_S = k_{S1} * Time_{REL} + k_{S2} * AE_{ALL} + k_{S3} * AD_{ALL} + k_{S4} * Planning + k_{S4} * Monitoring + k_{S5} * AverageEFF_{norm} + k_{S6}$

Methodology – case study 1

Experiment 1 – by playing an affectvely adapted 3D action video game, to try to:

- Recognize individual playing style using specific game metrics and compare it to the style measured by self-report:
  - Demographic data and former playing experience – 13 items
  - Playing style – 40 items
  - Learning style – 40 items
  - Big Five personality traits (openness to experience, conscientiousness, extraversion, agreeableness, and neuroticism) – 10 items (for further study)
  - Emotional adaptation – 5 questions
- Find correlations between the playing style and learning style
- Explore the effect of affect-based adaptations of content generation, DDA and audio-visual effects over:
  - preference to play the game
  - player´s performance and efficiency
  - difficulty of solved task

Case study 1 – Rush for Gold game

- A 3D video game using adaptation based on player performance, efficiency and emotional state using the FACE web service of SightCorp (https://face.sightcorp.com/)
- Developed by using Brainstorm eStudio (http://www.brainstorm.es/products/estudio/)
- Allows implicit recognition of ADOPTA playing styles in order to validate them to ones calculated by using self-report. The implicitly found style will be used for automatic selection of learning content appropriate to that style.
- Goal: to collect 12 bars of gold (bullions), which are flying, hidden or inside logic puzzles needed to be solved, all located in a 3D Egypt temple with enhanced audio-visual effects being object of adaptation, as well.
- The player can use a Strategy Planning Table (SPT):
  - represents a table with three rows for planning numbers of bars of the three groups available in the game
  - contains data about average effectivity of performance for collecting the gold bars of each group useful for building a strategy for optimal way of play.

Rush for Gold

Adaptable game features 1/3

1. Adaptive automation of game tasks and feedback in game:

A.1 Game-driven tasks:

- *explicit tasks* - game objectives (to shoot/discover gold bullions or to solve puzzles) adapt to the gameplay;
- *implicit tasks* - not explicitly stated by the game interface but expected to be fulfilled:
  - maximize your skills in shooting, discovering, solving and strategic planning of activities
  - collect as many gold bullions as possible

A.2 Player-driven tasks - created by the player thanks to his/her creativity within existing limitations of given game mechanics and leading to so called emergent gameplay

- how to find best position for shooting (depends on gun high and shooting angle)
- how to explore the temple with changing visual properties

Adaptable game features 2/3

2. Dynamic Difficulty Adjustment (DDA):

- *DDA by means of automatic level generation* - uses methods for procedural content generation
  - Logic puzzles have increasing dynamically their difficulty with higher player results and vice versa
- *DDA by means of adjusting level context*, i.e. game items for player interactions – means dynamic adaptation of level of inventory interacted by the player for specific game context, according to player's skill acquisition:
  - *Hidden billions are more difficult to be found* with player progress and higher affect (they are moved to more hidden places)
  - *Flying bullions change velocity & acceleration plus striking force* - changed with player efficiency as well with player´s emotions

Adaptable game features 3/3

3. Adaptation of audio-visual effects:

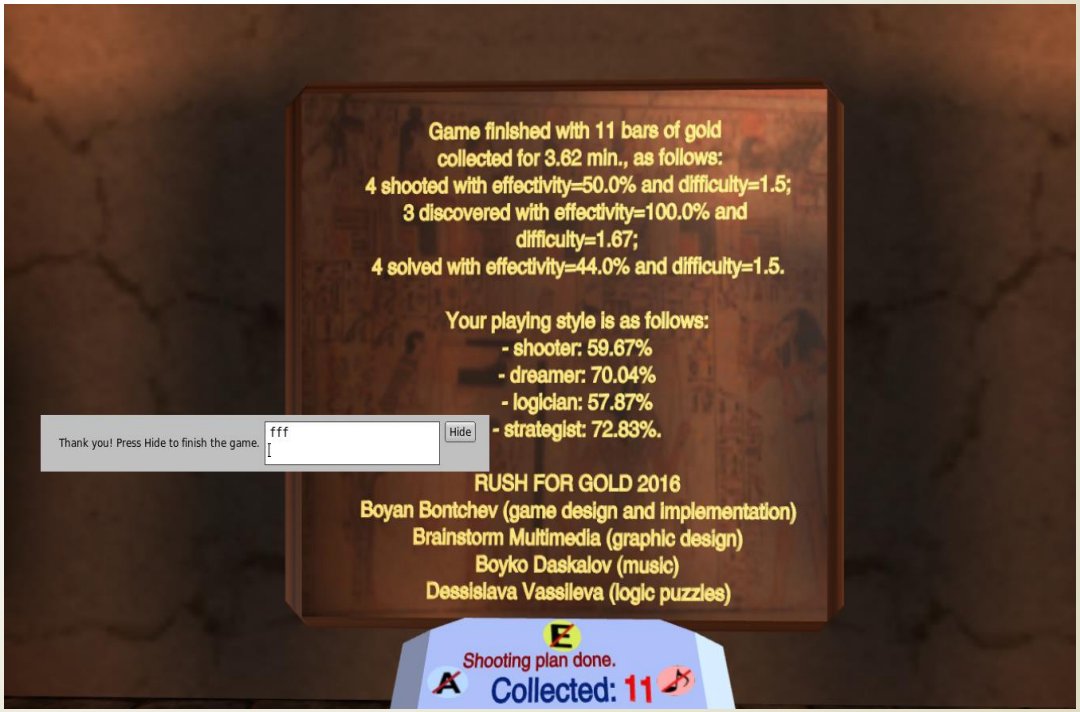
- according player´s affect (both emotions and arousal) using thresholds of happiness, fear, surprise and disgust level, there are adapted :
  - ambient light intensity
  - focus and contrast of game objects such as puzzle panels, buttons, gold bullions, statues, etc.
  - the volume of sound

Experiment (FMI-SU, March 2016)

- Executed at Sofia University, Bulgaria, with 34 volunteers (average aged 27, SD=10; 18 men and 16 women)
- They passed group explanation and demonstration (20 min.), procedure of informed consent (translated in Bulgarian, 15 min.), individual assisted trial (5-10 min.) and, finally, unassisted adaptive/non-adaptive game session to determine their style of play (15-20 min.).
- Half of the volunteers (N=17) played the game with emotional adaptation switched on (forming the experimental group), unlike the others (the control group).

Player style measurement - howto

- Implicitly during play time of specific mini-game
- Based on player's metrics for specific game tasks:
  - Performance (result)
  - Efficiency (result/effort)
  - Task difficulty
  - Relative play time, SMT updates & views (for Strategists)



Rush For Gold, part 2 - https://www.youtube.com/watch?v=aJe61bUDE40

Correlation b/n calculated through gameplay and reported playing style

Playing Style	Linear regression coefficients	r	p	N
C	interviews	0,791566	0,00000	34
	least squares	0,801089	0,00000	
D	interviews	0,769846	0,00000	
	least squares	0,785548	0,00000	
L	interviews	0,828592	0,00000	
	least squares	0,826615	0,00000	
S	interviews	0,632938	0,00004	
	least squares	0,643194	0,00004	

Prediction of learning style by the playing style calculated through game

Learning Style (quiz)	Playing Style (game)	Linear regression coefficients	Accuracy	N
Activist	Competitor	interviews	75,35%	34
		least squares	75,09%	
Reflector	Discoverer	interviews	78,30%	
		least squares	79,88%	
Theorist	Logician	interviews	83,33%	
		least squares	84,53%	
Pragmatist	Strategist	interviews	77,26%	
		least squares	83,99%	

Emotion-based adaptation in Rush for Gold

- The game adaptation control is at run time and implicit for the player
- The adaptation control makes the video game aligned to specific response patterns of individual players for bringing positive effect on playability and learning outcomes
- The adaptation process runs in the context of the game and aligns adaptable game features to player-centric metrics showing:
  - player's progress and performance
  - player´s arousal
  - player's emotions –inferred by face expression analysis
    - with negative valence: fear, anger, sadness and disgust
    - with positive valence: joy and surprise

Dynamic adjusting of task difficulty and light intensity

Type of emotional valence	Emotion value (E)	Arousal value (A)	Affectation level	Difficulty of shooting/discovering tasks (D)	Light intensity (LI)
Negative	E≥0.4	A≥7	High	$D_{curr} - 2*SAA$	$LI - 2*k*SAA$
Negative	0.2<E<0.4	3<A<7	Moderate	$D_{curr} - SAA$	$LI - k*SAA$
Negative	E≤0.2	A≤3	Low	D_{curr}	LI
Positive	E≥0.4	A≥7	High	$D_{curr} + 2*SAA$	$LI + 2*k*SAA$
Positive	0.2<E<0.4	3<A<7	Moderate	$D_{curr} + SAA$	$LI + k*SAA$
Positive	E≤0.2	A≤3	Low	D_{curr}	LI

Dynamic correction of difficulty of shooting/discovering tasks and illumination (light intensity) by emotion level for applying *positive affective feedback* and strength of affective adaptation (SAA)

Results about preference to play with emotion-based adaptation

- The quiz reveals (five-level Likert scale from 1 to 5):
  - certain preference to play the game with emotion-based adaptation (M=3.9, SD=1.1)
  - positive appreciation of that adaptation of shooting difficulty (M=4.0, SD=0.8)
  - the same for discovering difficulty (M=3.8, SD=0.7),
  - and brightness and contrast (M=4.1, SD=0.7).

Results about preferences to play with emotional adaptation

Positive statistically significant correlations (0,34÷0,55) between:

- *preferences to play with emotional adaptation* and
- *shooting/discovering efficiency, discovering performance and game session time*

reveal the beneficial impact of emotional adaptation inside the experimental group.

Results about audio-vidual adaptations

- Adapted brightness and contrast are correlated:
  - positively to solving performance (because of attracting player's attention to the puzzles)

  and

  - negatively to discovering performance (because of attracting player's attention to other objects)

Methodology – case study 2

A. Playing an action 3D video game (in adaptive/non-adaptive modes) for recognition of playing styles and, next, educational games with learning content adapted both to styles and player's affect.

B. Questionnaires about:

- Demographic data – 5 items
- Playing style – 40 items, and adaptation questions (4 items)
- Game engagement questionnair (**GEQ**) – 19 items
- Attention, relevance, confidence, and satisfaction (**ARCS**) questionnair – 16 items – applied to STRAMAG players and traditional learners
- All questionnaires applied for:
  - Recognition of individual playing style using specific game metrics for comparing it to the style calculated by the game
  - Exploring the effect of affect-based adaptation over:
    - player´s engagement and attention
    - learning outcomes
  - Evaluation of adaptation control – to be compared to in-game reports

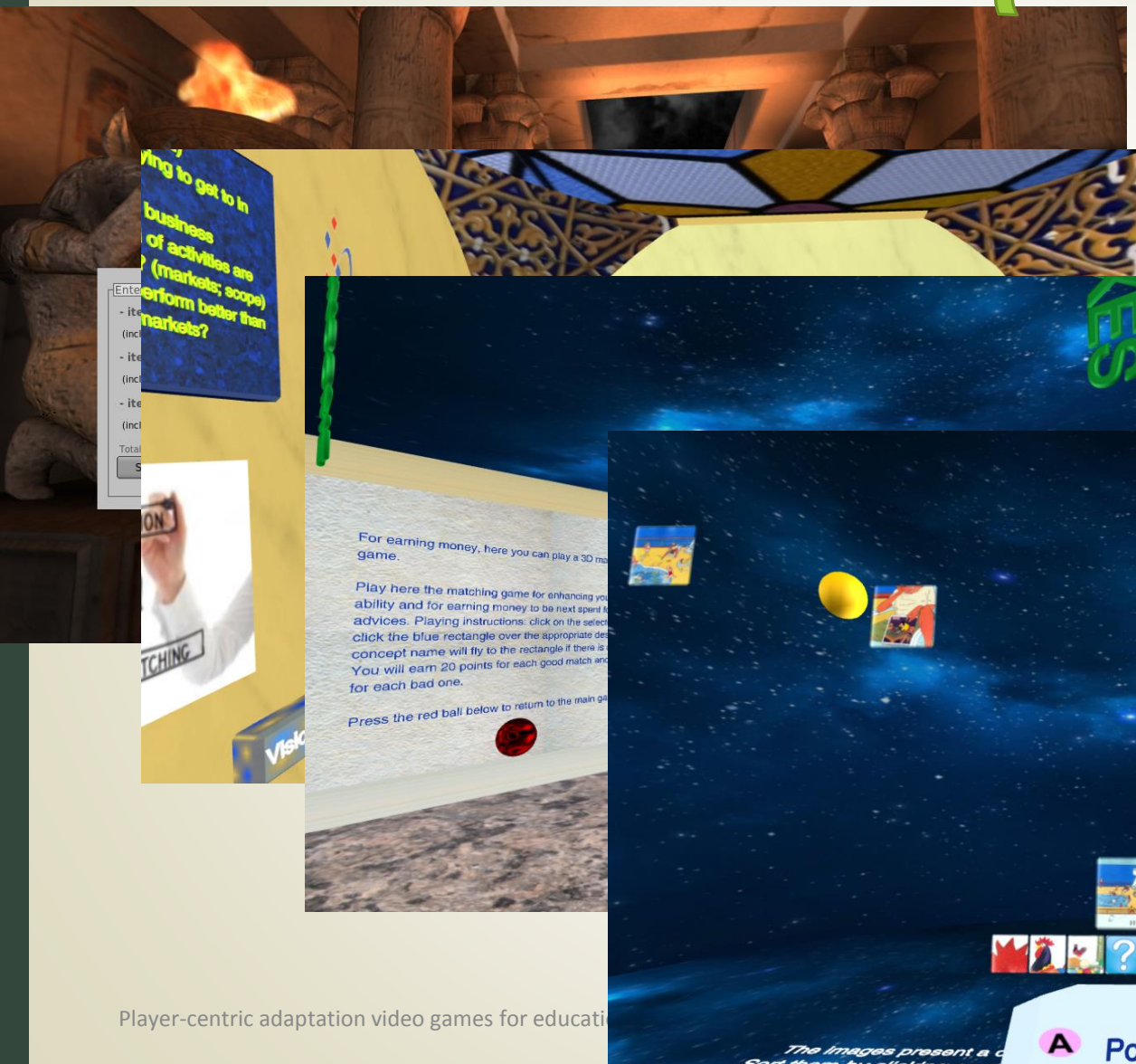
Adaptive games' sequence

Rush For Gold (playing/learning style calculated)

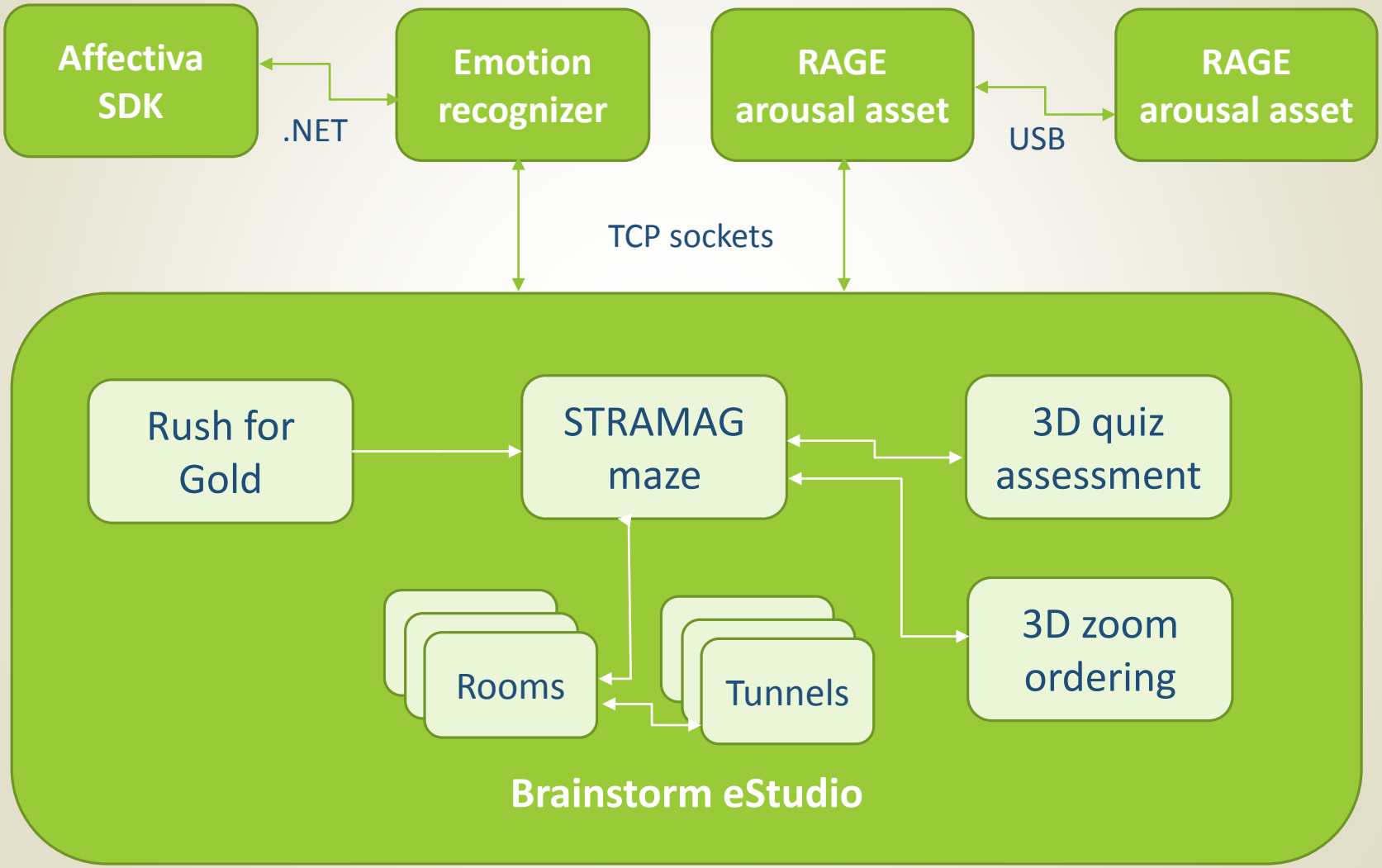
STRAMAG generated labyrinth (maze game)

3D quiz game (assessment)

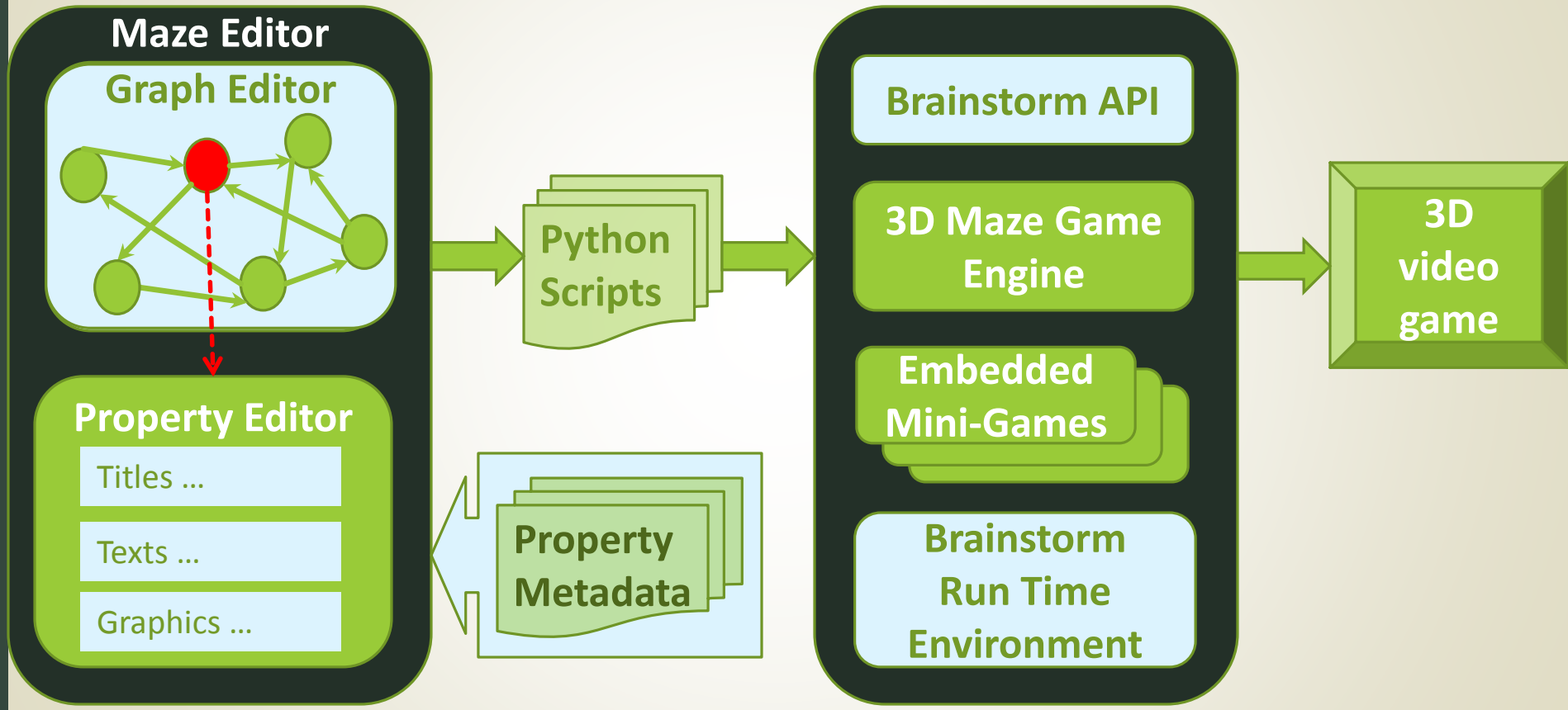
3D zoom puzzle



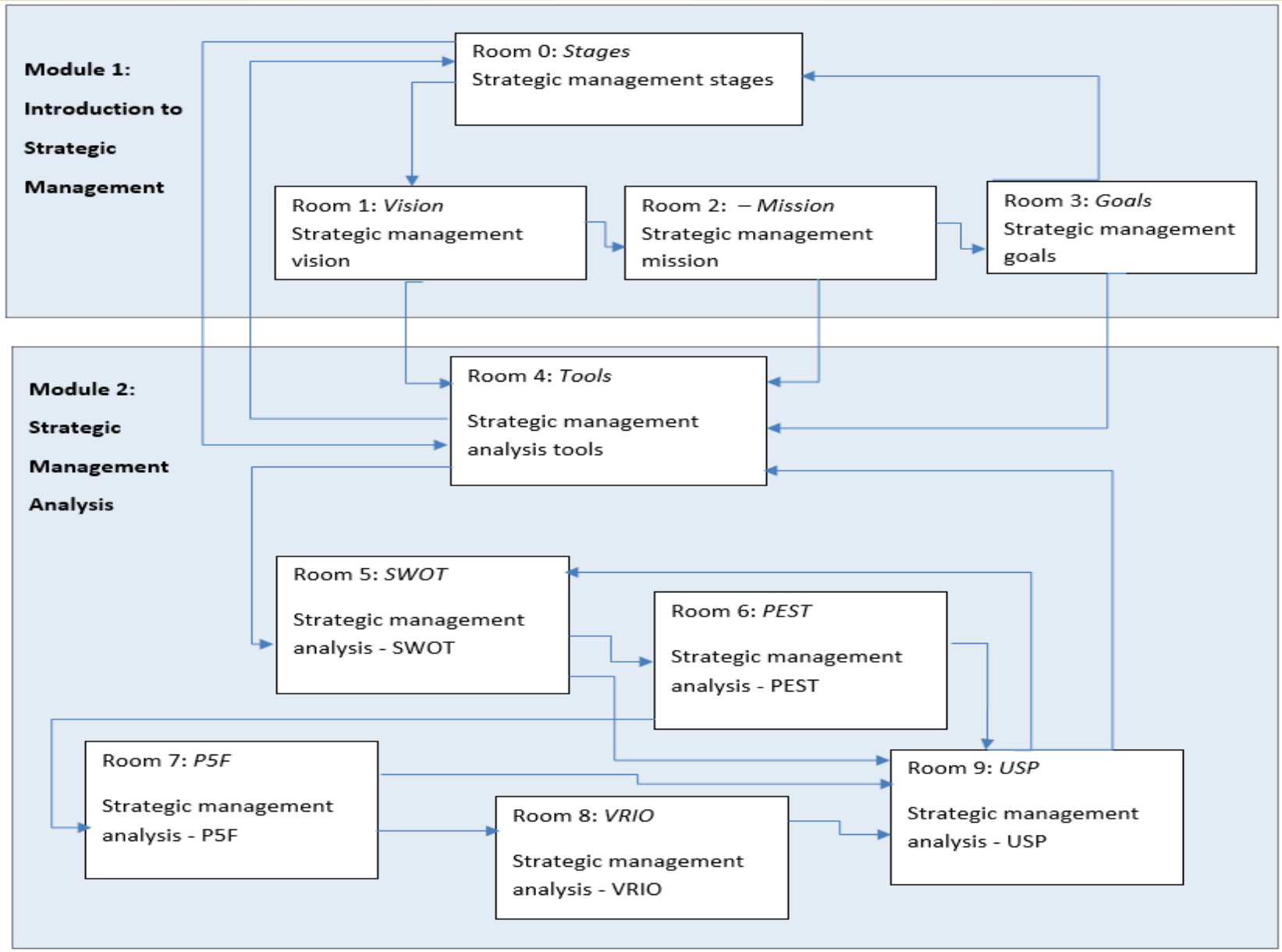
Case study 2 (June, 2016)



A platform for generation of customizable video maze games for education



STRAMAG (STRAtegic MAnagement Game)



In-game evaluation vs self-report

Statistic	ACP evaluation / Preference of adaptive gameplay	Happy with DDA of shooting task	Happy with DDA of discovering task	Happy with adaptation of light intensity
r	0,6575	0,8185	0,8396	0,8639
p	<0,0001	<0,0001	<0,0001	<0,0001

Correlation b/n calculated and reported playing styles

Playing Style	Linear regression coefficients	r	p	N
C	interviews	0,85902	0,00000	30
	least squares	0,89210	0,00000	
D	interviews	0,77113	0,00000	
	least squares	0,75937	0,00000	
L	interviews	0,83061	0,00000	
	least squares	0,82476	0,00000	
S	interviews	0,66216	0,00007	
	least squares	0,63621	0,00016	

Prediction of self-reported playing style by the style calculated throughout the game (N=30)

Playing Style (game)	Linear regression coefficients	Accuracy (no adapt.)	Accuracy (adapt.)
Competitor	interviews	59,95%	77,33%
	least squares	56,42%	84,18%
Discoverer	interviews	62,99%	74,22%
	least squares	66,89%	82,25%
Logician	interviews	60,45%	75,72%
	least squares	60,06%	74,94%
Strategist	interviews	75,82%	88,16%
	least squares	74,17%	88,36%

Benefits of adaptive gameplay vs non-adaptive gameplay

Mode .	Without affective adaptation		With affective adaptation		Student's paired two-tailed T-test
Game metric	**Mean**	**SD**	**Mean**	**SD**	**r**
Shooted eff.	0,3330	0,2193	0,4497	0,2550	0,0435
Shooted diff.	1,2493	0,2258	1,5520	0,3658	0,0000
Discovering eff	0,6780	0,1474	0,7670	0,1699	0,0027
Discovered diff.	1,6793	0,2536	1,8050	0,2909	0,0228
Solving eff.	0,5913	0,1964	0,7443	0,2403	0,0002
Solving diff.	2,6523	0,2372	1,9300	0,2983	0,0054
Relative time	0,5890	0,1585	0,7261	0,1742	0,0022
Avr. efficiency	0,5399	0,1020	0,6537	0,1264	0,0001
Average relative difficulty	0,6692	0,0643	0,7466	0,0694	0,0002

Correlations 1/2

Evaluation of affective adaptation	Preference of adaptation	Happy with adaptation of shooting	Happy with adaptation of discovering	Happy with adaption of illumination	Happy with overall affect-based adaptation
In-game evaluation	**0,6575**	**0,8185**	**0,8396**	**0,8639**	**0,7178**

	ARCS Questionnaire				Game Engagement Questionnaire				
	Atten-tion	Rele-vance	Confi-dence	Satis-faction	Presen-ce	Absorp-tion	Flow	Immer-sion	Engage-ment
AVR attention	0,3398	**0,4026**	0,2565	0,3211	-0,0113	0,1906	-0,0539	0,1412	0,1063
MAX attention	**0,5349**	**0,5510**	0,3579	0,3503	0,1398	**0,4689**	0,0130	0,1518	0,3025
AVR engagement	0,2703	0,1612	0,0692	0,0862	-0,0523	0,1309	-0,1324	-0,0661	-0,0258
AVR eye closure	**0,3633**	0,3555	0,0667	**0,3992**	0,1068	0,3385	0,1995	-0,0791	0,2232

Note: **bold** values have values of p<0,05

Correlations 2/2

	Emotion inferred by facial expressions					
Emotional state	**Sadness**	**Disgust**	**Anger**	**Surprise**	**Fear**	**Joy**
AVR attention	0,0035	0,2627	0,1699	0,1663	0,0345	0,2268
MAX attention	-0,1287	0,1733	0,0705	0,2931	-0,0651	0,0877
AVR engagement	0,0985	**0,8473**	0,2821	**0,3923**	0,1337	**0,8912**
AVR eye closure	-0,0894	0,1846	0,2501	0,3933	0,0893	0,1574

Note: **bold** values have values of $p<0,05$

Conclusions 1/2

- Player-centric adaptive game play possesses essential advantages compared to the non-adaptive gameplay
- The synergy of using player´s performance, emotions, and playing styles is very promising
- All they are identified at run time and used for adapting game mechanics, dynamics and audio-visual content, in a *dynamic and implicit* way.

Conclusions 2/2

- The results reveal a promising and positive appreciation of emotion-based adaptation and, as well, interesting statistically significant correlations between such adjusting of dynamic difficulty of tasks and player´s self-report.
- More experiments with real time player´s feedback on adaptation use, additional self-reporting and qualitative analyses are needed for revealing ***how such emotion-based adaptations affect game experience and playability, learning outcomes and consequences of flow***

Future work

- Emotionally-adaptive games and other software app's
- Dynamic adaptation control
- Software app's using user affectation:
  - HRV
  - TEMP
  - ….
- Web-based platforms for generation of educational games targeted to non-ICT people
- Semantic content management in applied games

Thank you for your attention!

- Discussion

- Videos at: https://www.youtube.com/watch?v=rSzM2RrceNw&index=1&list=PLs4ZK9XAjRxpROiCNQ1kdDR8SFpH-itmY
- More info at: http://adaptimes.eu/