Unveiling the Power of Affect during Learning

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What is affect?

Affect

- Feeling, mood, or emotion
- Affect encompasses multiple systems at multiple levels and at multiple time scales
- Signaling functions (Schwarz, 2012), pointing out gaps in knowledge (confusion)
  - Appraising events in terms of their value, goal relevance, and goal congruence (Izard, 2010)

NEUROBIOLOGY AND CONSCIOUSNESS

PHYCHOPHYSIOLOGY AND BODILY SENSATIONS

COGNITIVE AND MOTIVATIONAL COMPONENTS

Component process model

Emotion episode

- ***interrelated, synchronized changes*** in all or most components
- in response to evaluation of an external or internal stimulus
- relevant to major concerns of the individual

Relationships between organismic subsystems and the functions and components of emotion

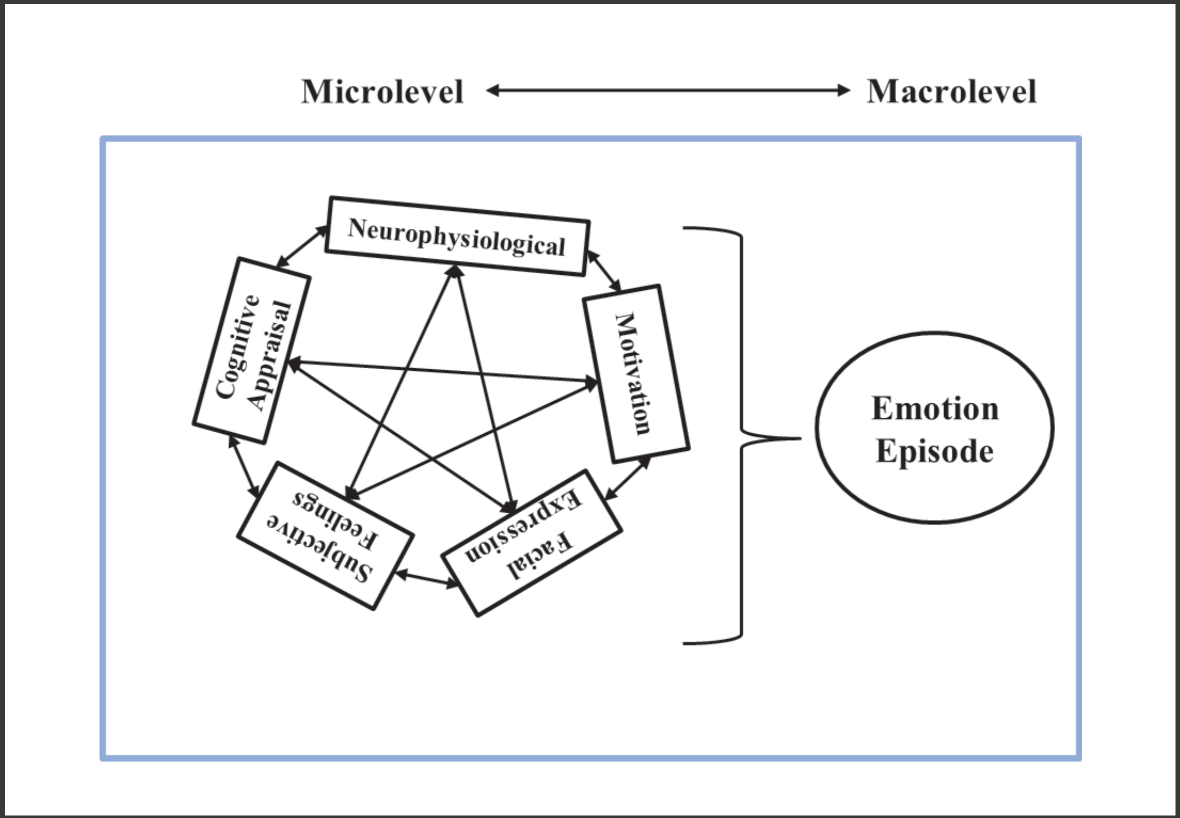
Emotion function	Organismic subsystem and major substrata	Emotion component
Evaluation of objects and events	Information processing (CNS)	Cognitive component (appraisal)
System regulation	Support (CNS, NES, ANS)	Neurophysiological component (bodily symptoms)
Preparation and direction of action	Executive (CNS)	Motivational component (action tendencies)
Communication of reaction and behavioral intention	Action (SNS)	Motor expression component (facial and vocal expression)
Monitoring of internal state and organism–environment interaction	Monitor (CNS)	Subjective feeling component (emotional experience)

Note: CNS = central nervous system; NES = neuro-endocrine system; ANS = autonomic nervous system; SNS = somatic nervous system.

Scherer, K. R., Schorr, A., & Johnstone, T. (Eds.). (2001). Appraisal processes in emotion: Theory, methods, research. Oxford University Press.

Component process model

The ***process*** consists of the coordinated changes over time



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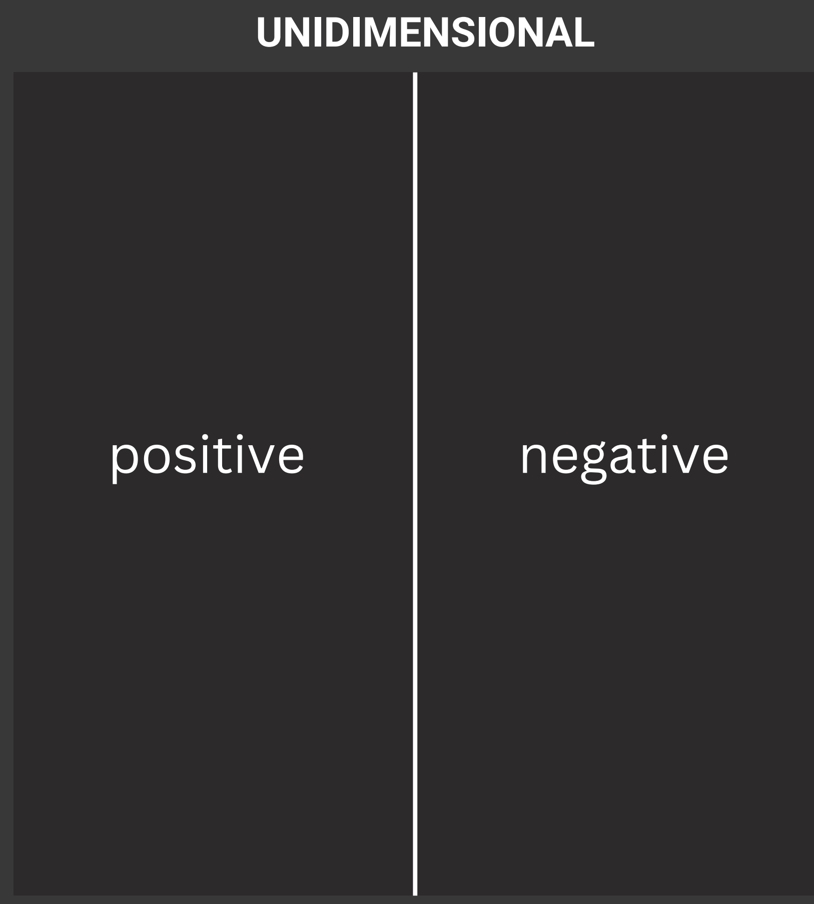
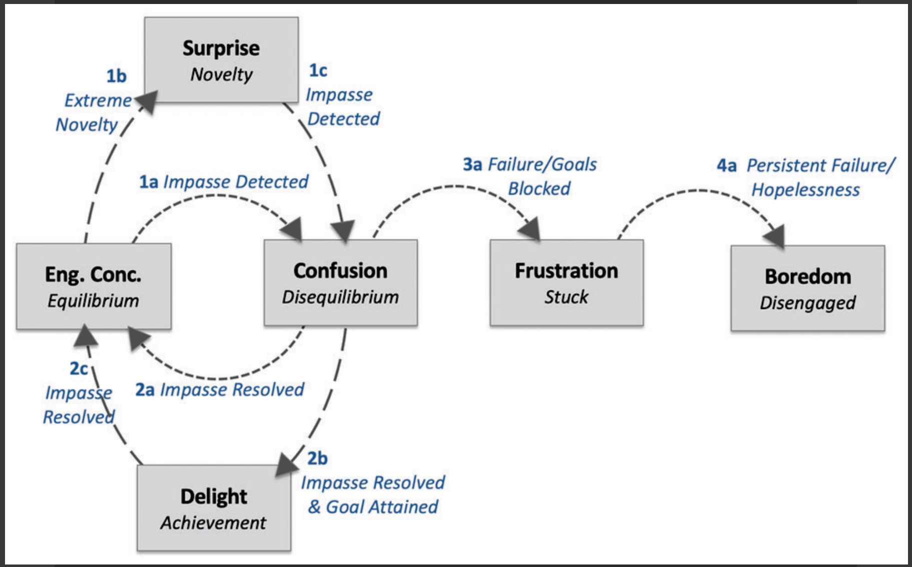
Valence



Model of Affective Dynamics

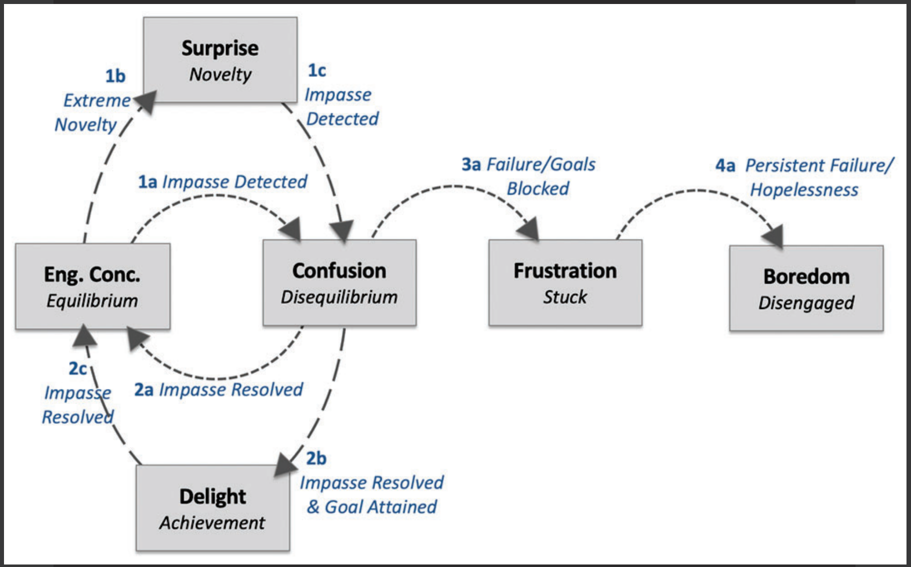


(D'Mello & Graesser, 2012)

D’Mello, S., & Graesser, A. (2012). Dynamics of affective states during complex learning. Learning and Instruction, 22(2), 145-157.

Model of Affective Dynamics

- Valence
- Temporal dimension



(D'Mello & Graesser, 2012)

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Affect sequence	Expected interpretation
Engagement ⟶ confusion ⟶ delight ⟶ engagement	The student has fully resolved the source of confusion and returned to working on the task
Confusion ⟶ delight	The student recently resolved the source of confusion, but has not yet returned to engagement with the task
Confusion ⟶ frustration	The student became frustrated after not resolving the source of confusion, but has not disengaged
Engagement ⟶ confusion ⟶ frustration ⟶ boredom	The student did not resolve the source of confusion, and disengaged instead

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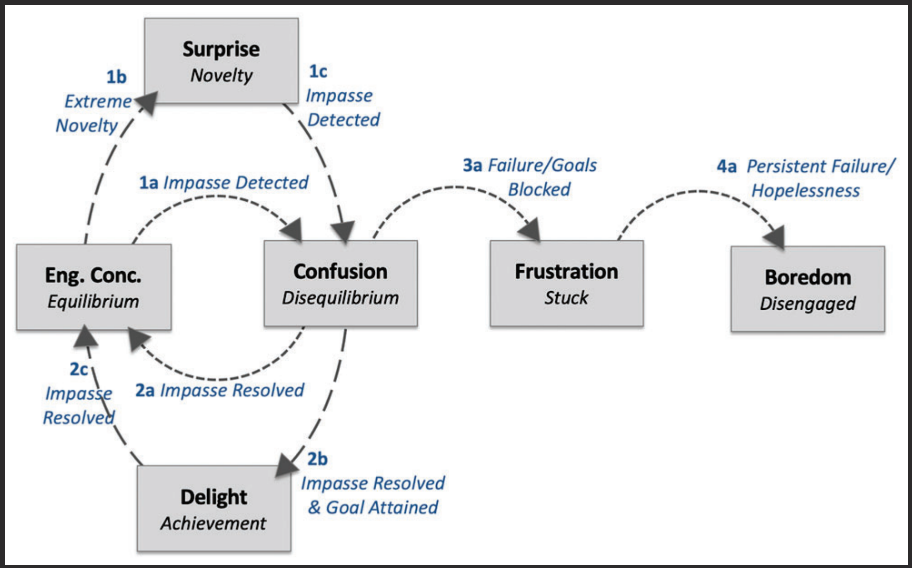
Empirical does not match theoretical

- Baker et al (2010)
- Lee et al (2011)
- Liu et al (2013)
- D'Mello et al. (2014)
- Andres et al. (2019)
- Karumbiah et al. (2022)



Challenges

- Methodological
  - Typically rely on interval data
  - Need for fine-grain and continuous data on multiple affective dimensions

- Analytical
  - Model dynamically

Leading Questions

How to measure affect as a dynamic process?

How to model affect as a dynamic process?

Affective Dynamics and Cognition with Crystal Island

Game-based learning environments foster emotional engagement via mechanics to enhance learning (Clark & Tanner-Smith, 2016; Plass et al., 2020)

RQ: Are there dynamic relationships between time expressing frustration, confusion, and neutral states and time engaging in scientifically reasoning?

Cloude, E. B., Dever, D. A., Hahs-Vaughn, D. L., Emerson, A. J., Azevedo, R., & Lester, J. (2022). Affective Dynamics and Cognition During Game-Based Learning. IEEE Transactions on Affective Computing, 13(4), 1705-1717.

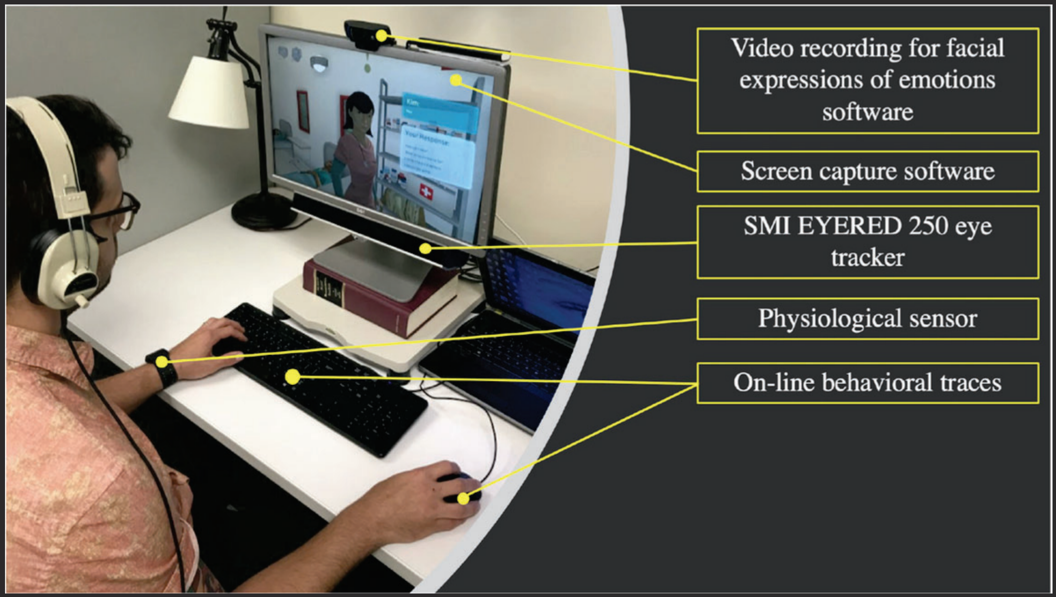
Methods

Sample of 78 Undergraduates (67% females)

- Age: 20 years
- 69% White
- 71% played 0-2 hrs of video games/week

Random assignment to the full (n=62), restricted (n=16), no agency

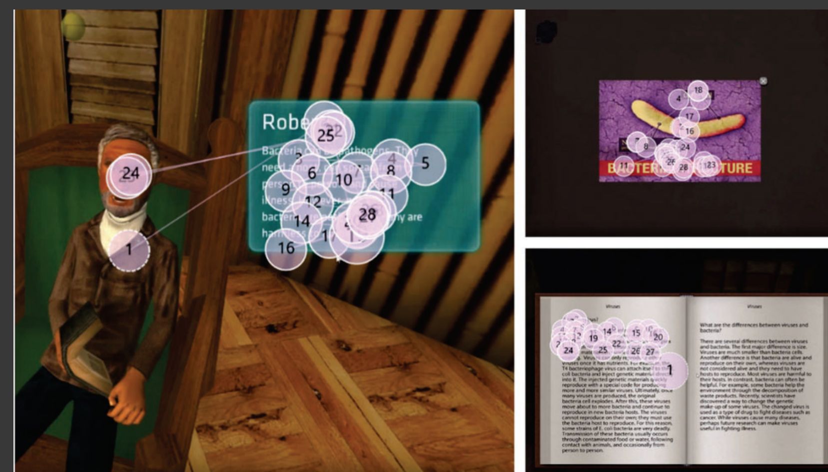
- Restricted agency: 78 mins
- Full agency: 81 mins



Data Coding and Scoring (1)

Scientific reasoning:

- Time engaging in scientific reasoning = overlap in
  - Eye gaze fixations using Areas of Interest
  - Log file interaction with game elements (Cloude et al., 2020)



Variables	Data channels	Game elements
Action 1: gathering information	Timestamped log files and eye fixations	Reading books, research articles, and posters; talking to NPCs.
Action 2: hypothesis generation	Timestamped log files and eye fixations	Backpack, food items, first field in the diagnosis worksheet.
Action 3: experimental testing	Timestamped log files and eye fixations	Final diagnosis field on the worksheet, concept matrix, and scanner.

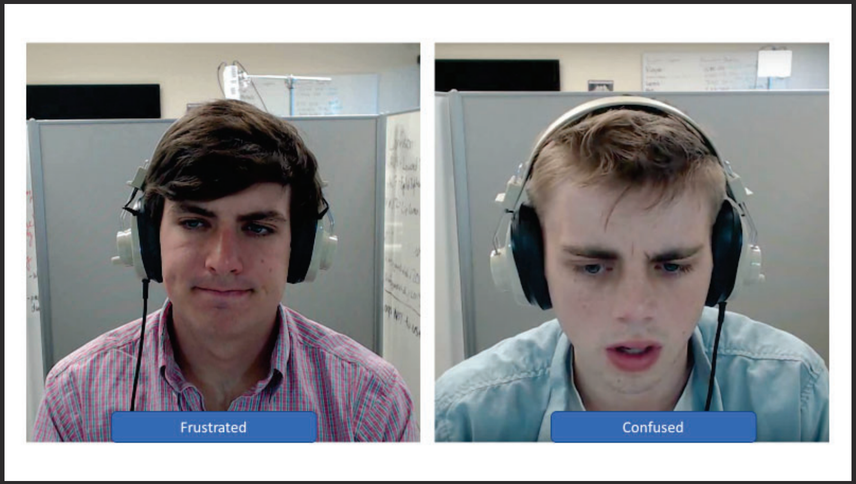
Cloude, E. B., Dever, D. A., Wiedbusch, M. D., & Azevedo, R. (2020). Quantifying scientific thinking using multichannel data with crystal island: Implications for individualized game-learning analytics. Frontiers in Education, 572546.

Data Coding and Scoring (2)

Emotions:

- Time expressing confused, frustrated or neutral states
  - AUs via iMotions
  - Facial landmarks deviated from baseline (neutral)

- Confused
- Frustrated
- Neutral



Statistical Analysis

Multi-level Growth Model

- Fixed term - between-subject variability
- Random term - within-subject variability

Two-level growth models:

- Level 1: within-individuals (15,882)
- Level 2: between-individuals (78)
    - Pre-test scores
    - Agency condition
    - Action

Unconditional Models:

$$Y_{ij} = \lambda_{00} + \lambda_{01}{}^{*}(Time)_{ij} + \sigma_{0j} + \sigma_{1j}{}^{*}(Time)_{ij}e_{ij} \quad (1)$$

View Source

where Y_{ij} describes the outcome variable (e.g., time scientific reasoning), lambda$_{00}$ and λ_{01} are, respectively, mean initial status and average growth rate. The symbols σ_{0j}, σ_{01}, and e represent, respectively, residual variance in initial status, residual variance in growth rate, and within-person residual variance.

Condition Models:

$$\begin{aligned} Y_{ij} = {} & \lambda_{00} + \lambda_{01}{}^{*}(Time) + \lambda_{02}{}^{*}(Action) \\ & + \lambda_{03}{}^{*}(FacialExpression) \\ & + \lambda_{04}{}^{*}(FacialExpression)^{*}(Time) \\ & + \lambda_{05}{}^{*}(PreTestScore) + \lambda_{06}{}^{*}(ExperimentalCondition) \\ & + \sigma_{0j} + \sigma_{1j} + e_{ij} \end{aligned} \quad (2)$$

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where Y_{ij} represents the outcome variable (e.g., time scientifically reasoning). λ_{0j} and λ_{1j}, respectively, represented the average initial status and average growth rate for predictors. Symbols σ_{0j}, σ_{1j}, and e_{ij}, represent, respectively, residual variance at initial status, residual variance in growth rate, as well as within-individual residual variance.

Are there dynamic relationships between time expressing frustrated, confused, and neutral states and scientifical reasoning?

Three separate models for each emotion

	Frustration	Confusion	Neutral
Variable	Estimate (*SE*)	Estimate (*SE*)	Estimate (*SE*)
Fixed effects			
Mean initial status	114.97 (27.13)	**140.38*** (21.11)	**92.59*** (29.43)
Mean growth rate	**-0.05*** (0.01)	**-0.05*** (0.01)	**-0.05*** (0.01)
Emotion duration	**0.32*** (0.05)	**0.26*** (0.03)	**0.40*** (0.05)
$Action_1$	**-115.30*** (4.54)	**-116.37*** (3.77)	**-114.38*** (1.93)
$Action_2$	**-84.19*** (2.93)	**-84.78*** (4.11)	**-83.57*** (2.25)
$Action_3$	**-116.41*** (12.58)	**-117.03*** (7.03)	**-114.84*** (5.35)
Pre-test scores [Level 2]	-65.89 (50.04)	**-93.00*** (38.86)	-53.84 (53.39)
Experimental $condition_1$ [Level 2]	**50.31*** (15.26)	**33.03*** (12.03)	-4.94 (16.28)
Random effects			
Within-individual	53.41	53.55	53.31
Initial status	82.31	62.89	97.66
Growth rate	**0.05***	0.04	**0.05***
Emotion duration	**0.37***	**0.27***	**0.40***
$Action_1$	37.55	**30.18***	10.51
$Action_2$	22.10	**33.67***	14.53
$Action_3$	110.29	**60.68***	45.38
Deviance	172787	172672	172575
ICC	0.70	0.58	0.77
Pseudo-R^2 (fixed effects)	0.25	0.30	0.35
Pseudo-R^2 (total effects)	0.90	0.85	0.91

*Note. *$p < 0.05$; Action1=Information gathering, Action2=Hypothesis generation; Action3=Experimental testing*

Key Takeaways

- More frustrated and confused predicted more engagement in scientific reasoning
- Within-subject variability explained large portion of outcome variable
    - Individual differences (e.g., values, goals)
- More prior knowledge predicted less engagment in scientific reasoning
    - May be moderated by confusion

Case Study:
Modeling Confusion as a Non-linear Dynamical System

Adaptive Complex Systems theory

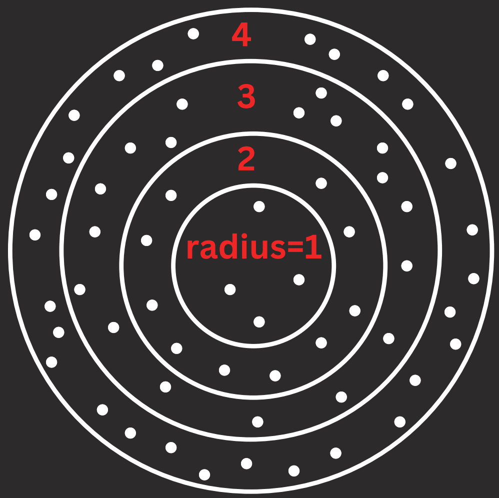
Nonlinear dynamical systems theory

Recurrence quantification analysis is a nonlinear time series analysis

- Sequential organization in a time-series

Embedding Parameters:

- Time delay = high-dimensional phase-space trajectory reconstruction (Takens, 1981)
- Radius = defines the window of recurrence plots



Sample

Sample of 80 participants

- Age = 20.12 (SD=1.57)
- 66% female

- Experimental design:
  - Random assignment: Full (n=51), Restricted (n=29)
  - Pre-test
  - Calibrated to Sensors
  - Gameplay
  - Post-test

Research Questions

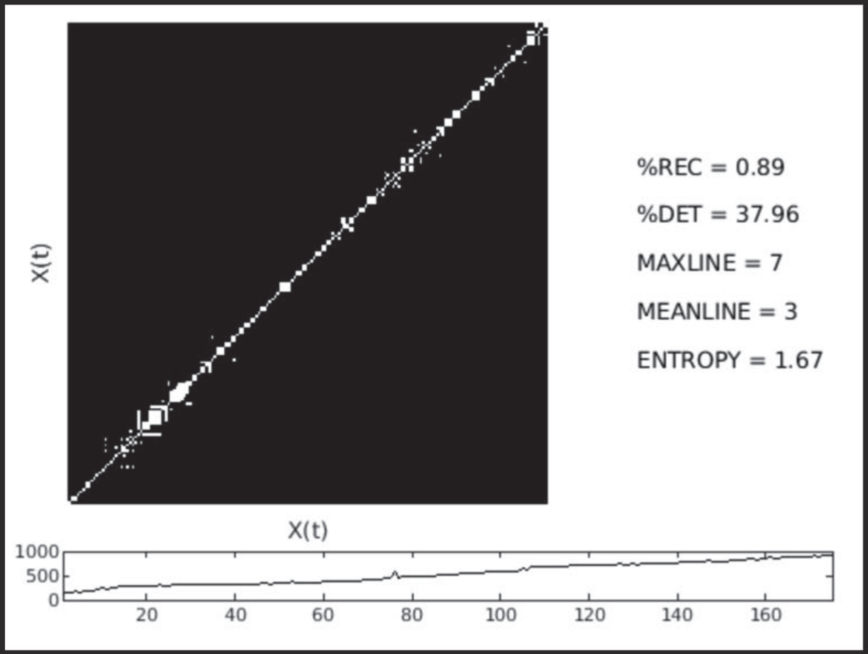
- Do repetitive instances of confused facial expressions differ between full and partial agency conditions during game-based learning?
- Do repetitive instances of confused facial expressions relate to post-test scores while controlling for agency and pre-test scores?

Do repetitive instances of confused facial expressions differ between full and restricted agency conditions during game-based learning?

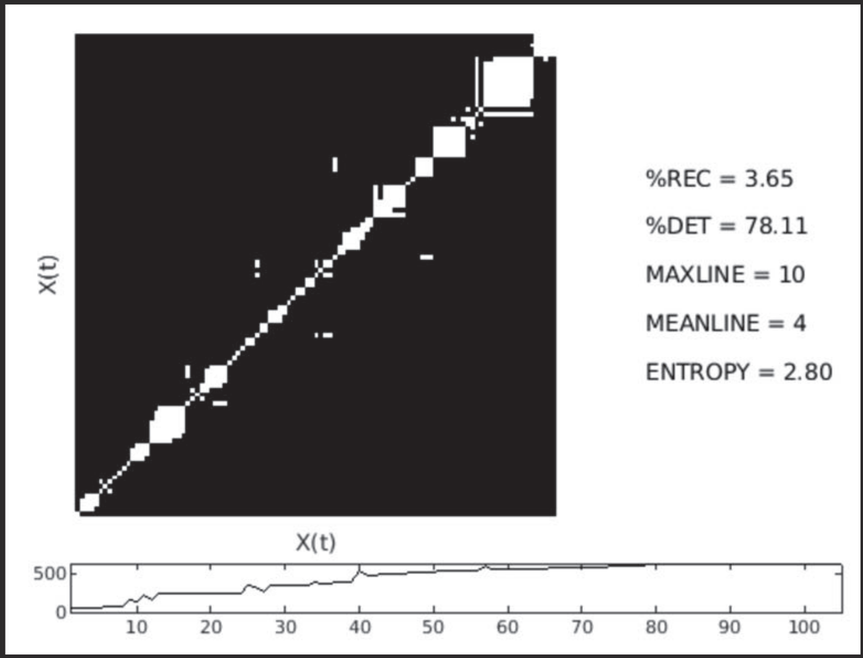
- Radius of .01 = smallest window
- A *t* test revealed <u>no</u> significant differences in the rate of repetitive confused facial expressions between restricted (M=1.46) and full (M=1.50) agency conditions, p=.3106.

This suggests that learners expressed similiar repetitive rates of confused facial expressions during game-based learning regardless of agency

Do repetitive instances of confused facial expressions differ between full and restricted agency conditions during game-based learning?



Lowest RR%



Highest RR%

Do repetitive instances of confused facial expressions during scientific-reasoning actions relate to post-test scores while controlling for agency and pre-test scores?

Multiple linear regression

Regression estimates of associations with post-test scores.

	Beta		Std. Error
Intercept	**1.096***		0.244
$Condition_1$	**-1.10***		0.335
Experimental Testing (Action 1)	0.558		0.299
Hypothesis Generation (Action 2)	**0.622***		0.269
Information Gathering (Action 3)	0.347		0.296
Duration	0.002		0.001
Recurrence Rate of Confusion	**-0.816***		0.165
Pre-test Scores	-0.551		0.430
Recurrence rate*$Condition_1$	**1.228***		0.234
F		**68.91***	
Df		31,48	
Adjusted R^2		**0.342**	

Note. $*p < 0.05$.

Key Takeaways

- More recurring time expressing confusion was detrimental to post-test scores
- Positive interaction between restricted agency and confusion on post-test scores
- How to best determine the parameters of RQA
  - 2-5% for human systems (Webber & Zbilut, 2005)
  - Increase radius
- Multiple signals of confusion

Future Work

- Measure and model multiple dimensions of an emotion episode

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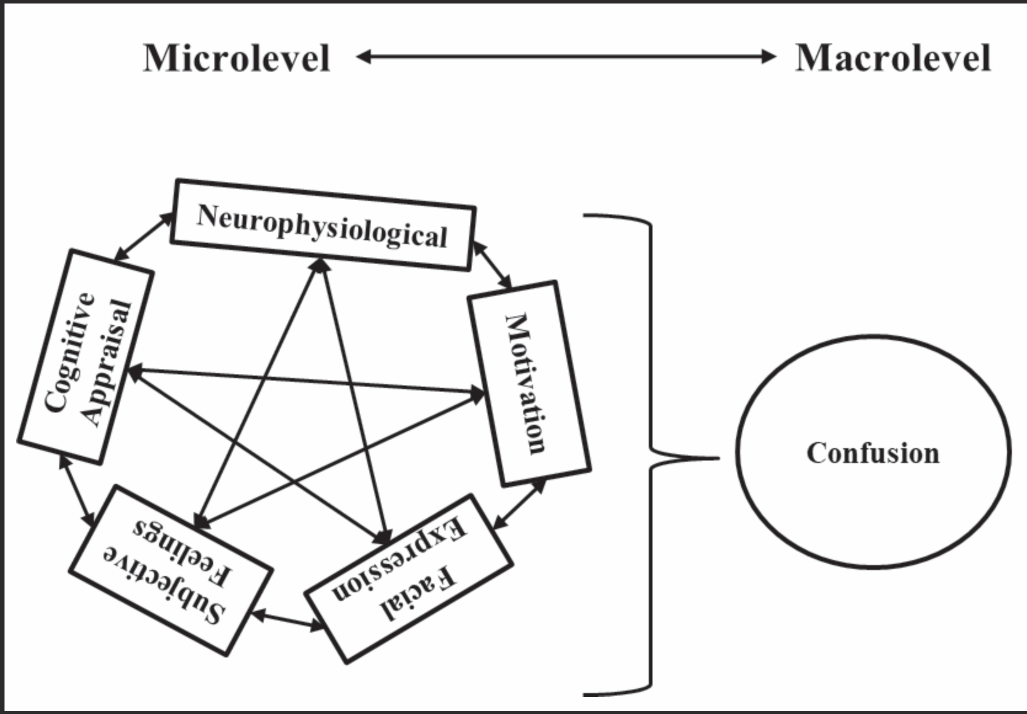
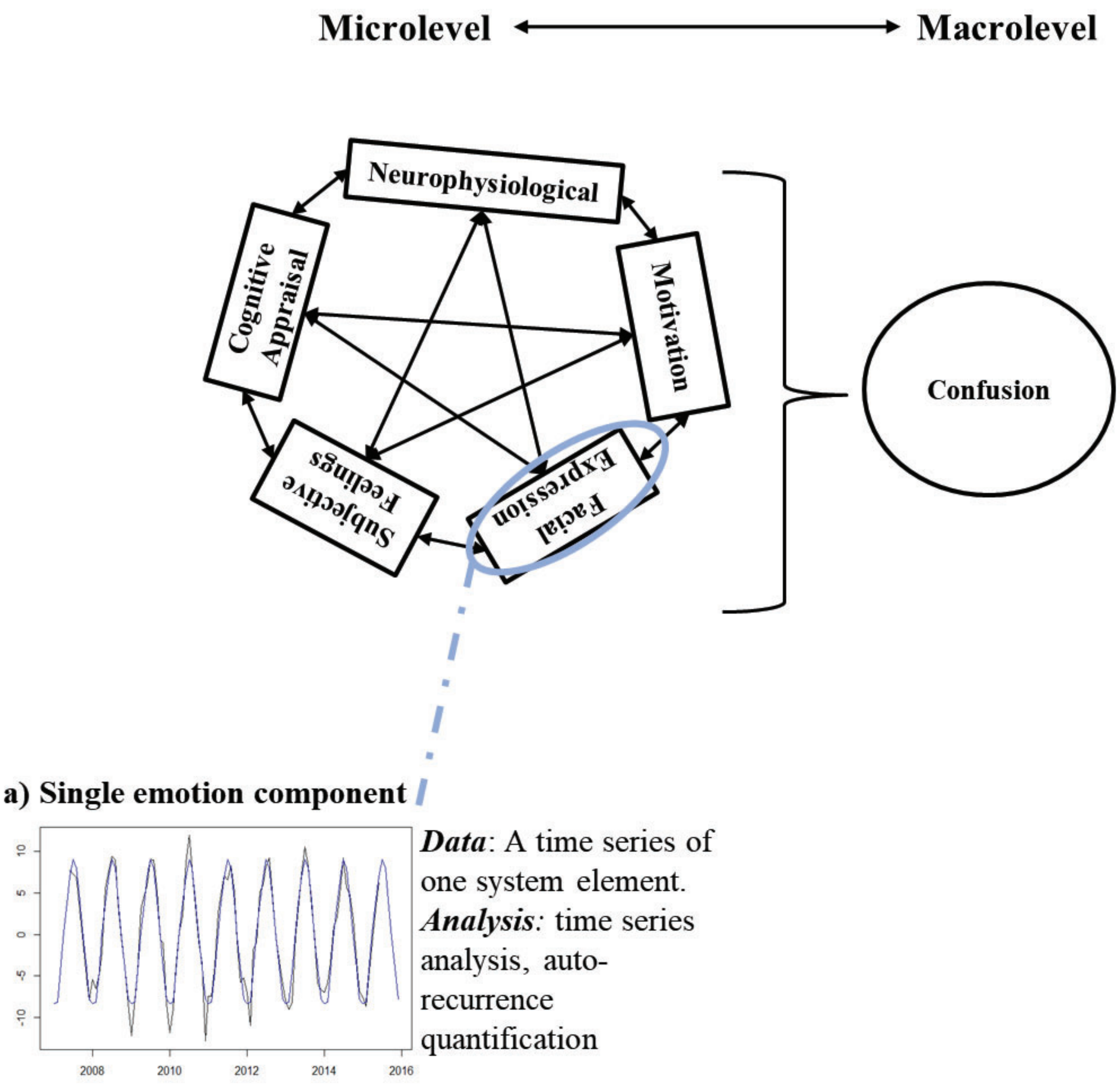
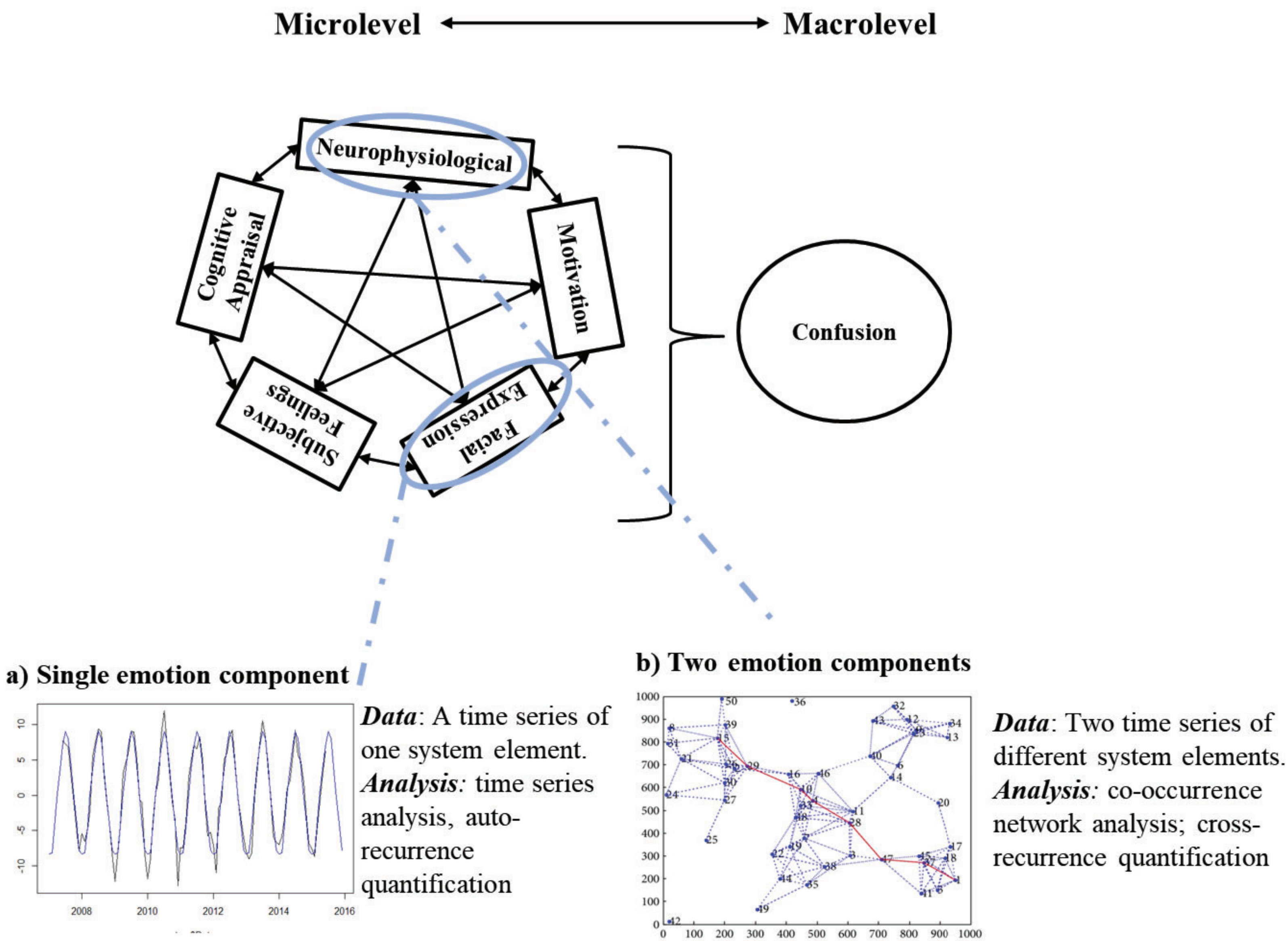



Microlevel
Macrolevel
Neurophysiological
Cognitive Appraisal
Motivation
Subjective Feelings
Facial Expression
Confusion
a) Single emotion component
Data: A time series of one system element.
Analysis: time series analysis, auto-recurrence quantification
10
5
0
-5
-10
2008
2010
2012
2014
2016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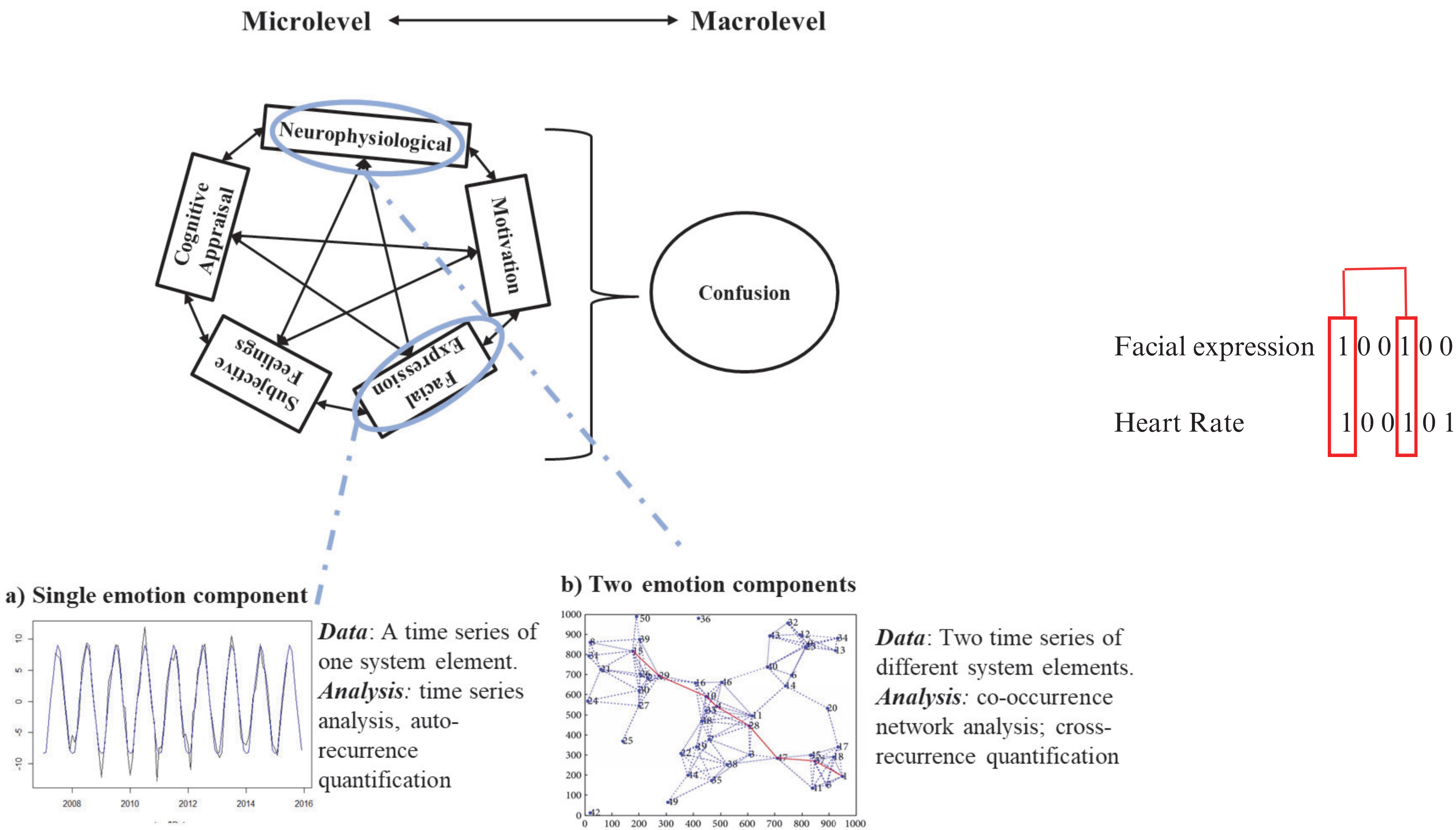
Analysis: time series analysis, auto-recurrence quantification
b) Two emotion components
Data: Two time series of different system elements.
Analysis: co-occurrence network analysis; cross-recurrence quantification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Facial expression 1 0 0 1 0 0
Heart Rate 1 0 0 1 0 1
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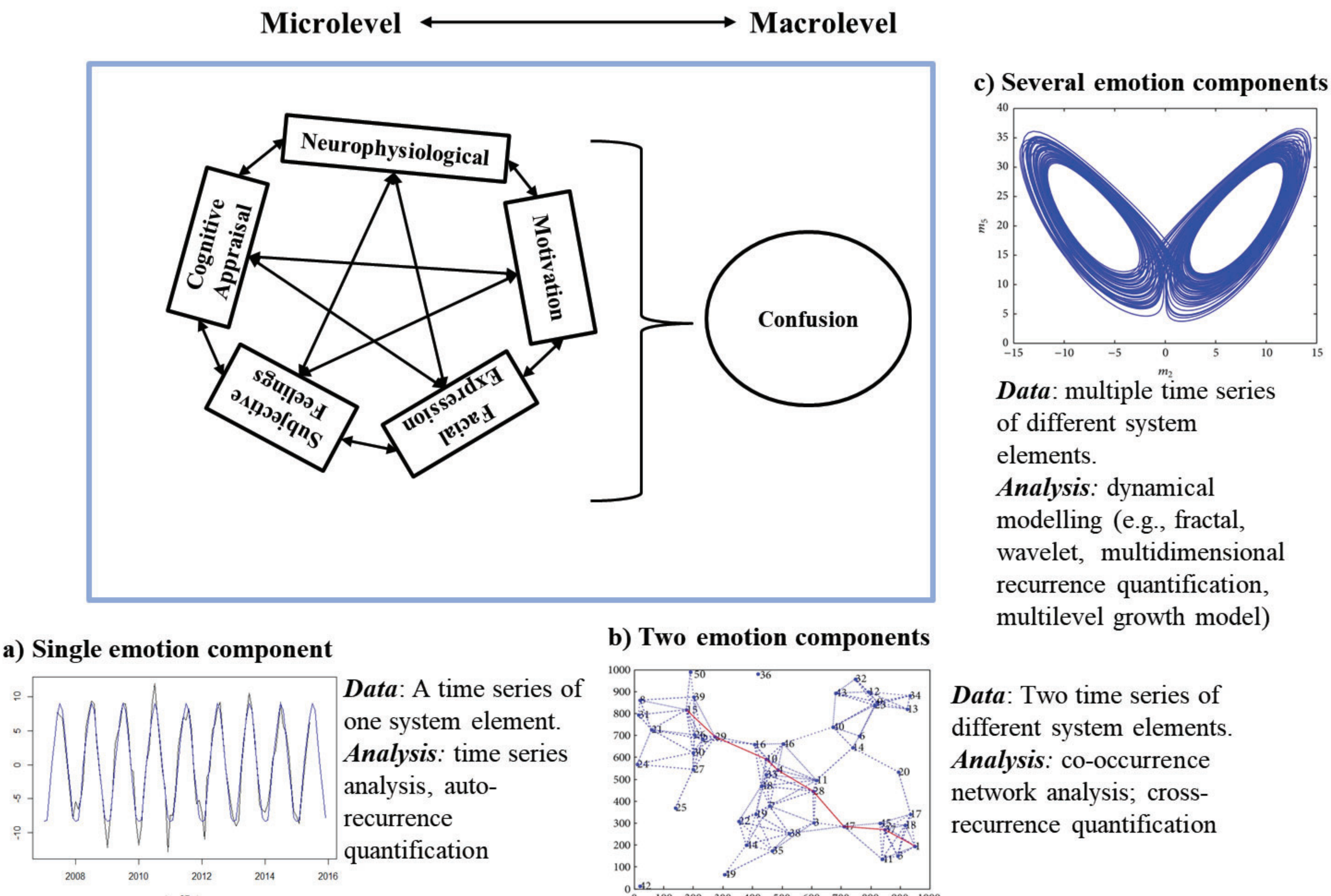

Microlevel
Macrolevel
Neurophysiological
Cognitive Appraisal
Motivation
Subjective Feelings
Facial Expression
Confusion
c) Several emotion components
Data: multiple time series of different system elements.
Analysis: dynamical modelling (e.g., fractal, wavelet, multidimensional recurrence quantification, multilevel growth model)
a) Single emotion component
Data: A time series of one system element.
Analysis: time series analysis, auto-recurrence quantification
b) Two emotion components
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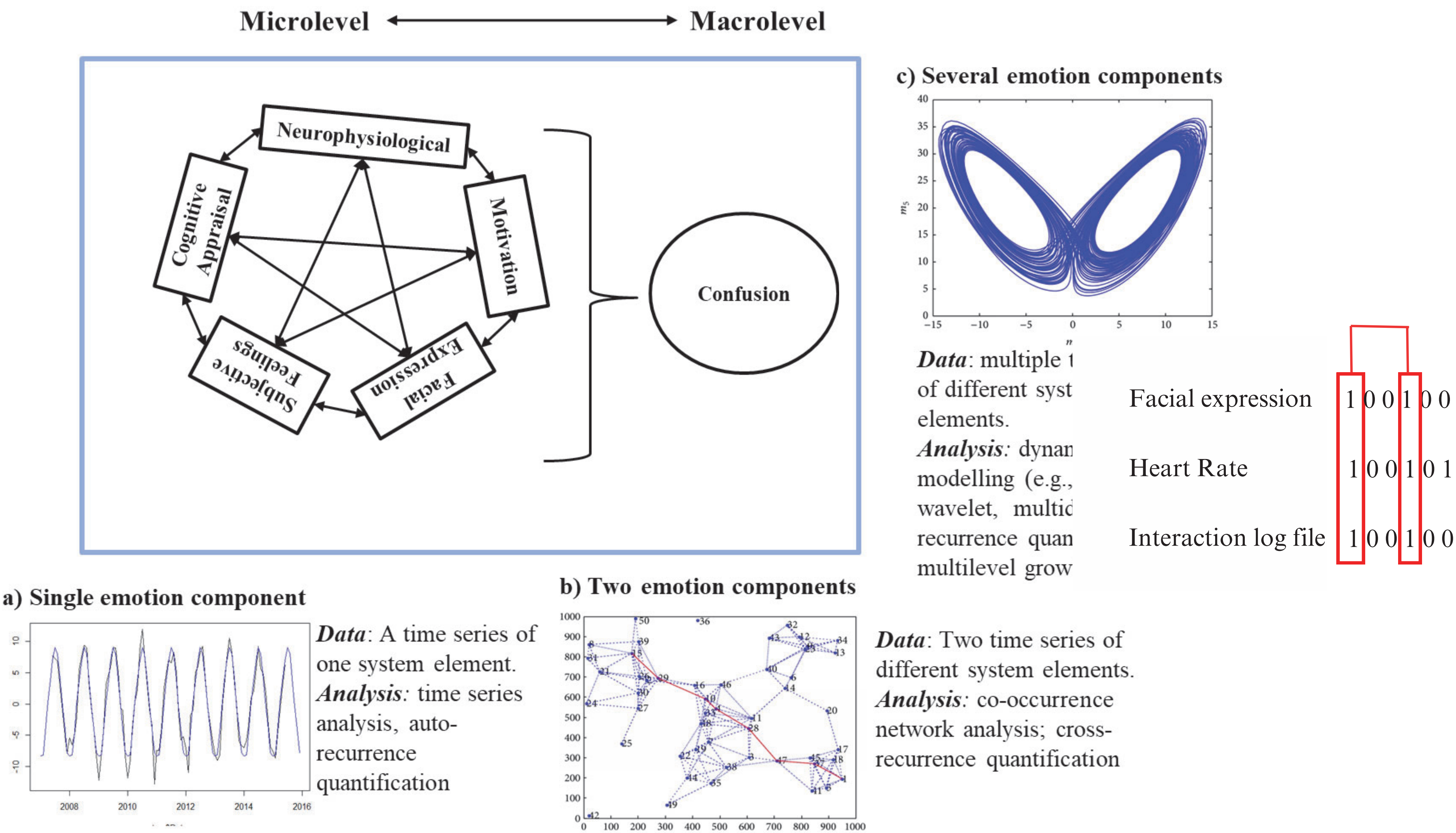

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Thanks for your time!

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