ANR/DFG - CEEGE
Chess Expertise from Eye Gaze and Emotion

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ANR/DFG CEEGE
Chess Expertise from Eye-Gaze and Emotion

Plan

- Project and Research Questions
- Experimental Instrument
- Results from First Experiment
- A Cognitive Model: WM, Chunks and Emotions
- Second Experiment
- Applications, Limitations, Open Challenges
- Bibliography

CEEGE: Inria Grenoble Team

INRIA Grenoble Rhone-Alpes:

- Thomas Guntz, Doctoral Student
- Dr. Dominique Vaufreydaz (Multi-modal Perception, Social Robotics)
- Prof. Philippe Dessus (Cognitive Science, Education Technologies)
- Dr. Raffaella Balzarini (Eye-tracking, user centered design)
- Prof. James L. Crowley (Computer Vision, Robotics, Multi-modal Interaction)

CEEGE: CITEC, Univ. Bielefeld, Team

Center of Cognitive Interaction Technology (CITEC)

Univ. Bielefeld, Bielefeld, Germany

- Prof. Thomas Schack (Neurocognition)
- Dr. Kai Essig, (Neurocognition)
- Thomas Kuchelman (doctoral student)

ANR/DFG CEEGE
Chess Expertise from Eye-Gaze and Emotion

Amount: 230 481 €

Contract Dates: 1 Dec 2015 to 30 Nov 2019 (4 years)

Scientific Project: 1 Oct 2016 to Sept 2019 (3 years)

The dates for the scientific project have been chosen to correspond to the 36 month doctoral contract of Thomas Guntz, doctoral student funded by the project. (In France, doctoral studies are supposed to last only 36 months).

CEEGE: Research Questions

1) What are the most effective techniques to observe and model the emotions of subjects engaged in solving problems?
2) Is it possible to use eye-gaze and emotion to discover and model the understanding and reasoning of a person engaged in solving problems?
3) Are techniques for deep learning more effective than traditional cognitive science for modeling the understanding and predicting the actions of subjects?

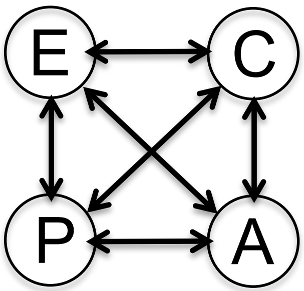
Why Emotions?

Emotion and Cognition: Two Complementary Systems

<u>Emotion</u>:
Fast, Reactive, Predictable.

Enables rapid reaction to threats and opportunities.

Kahneman's System 1?



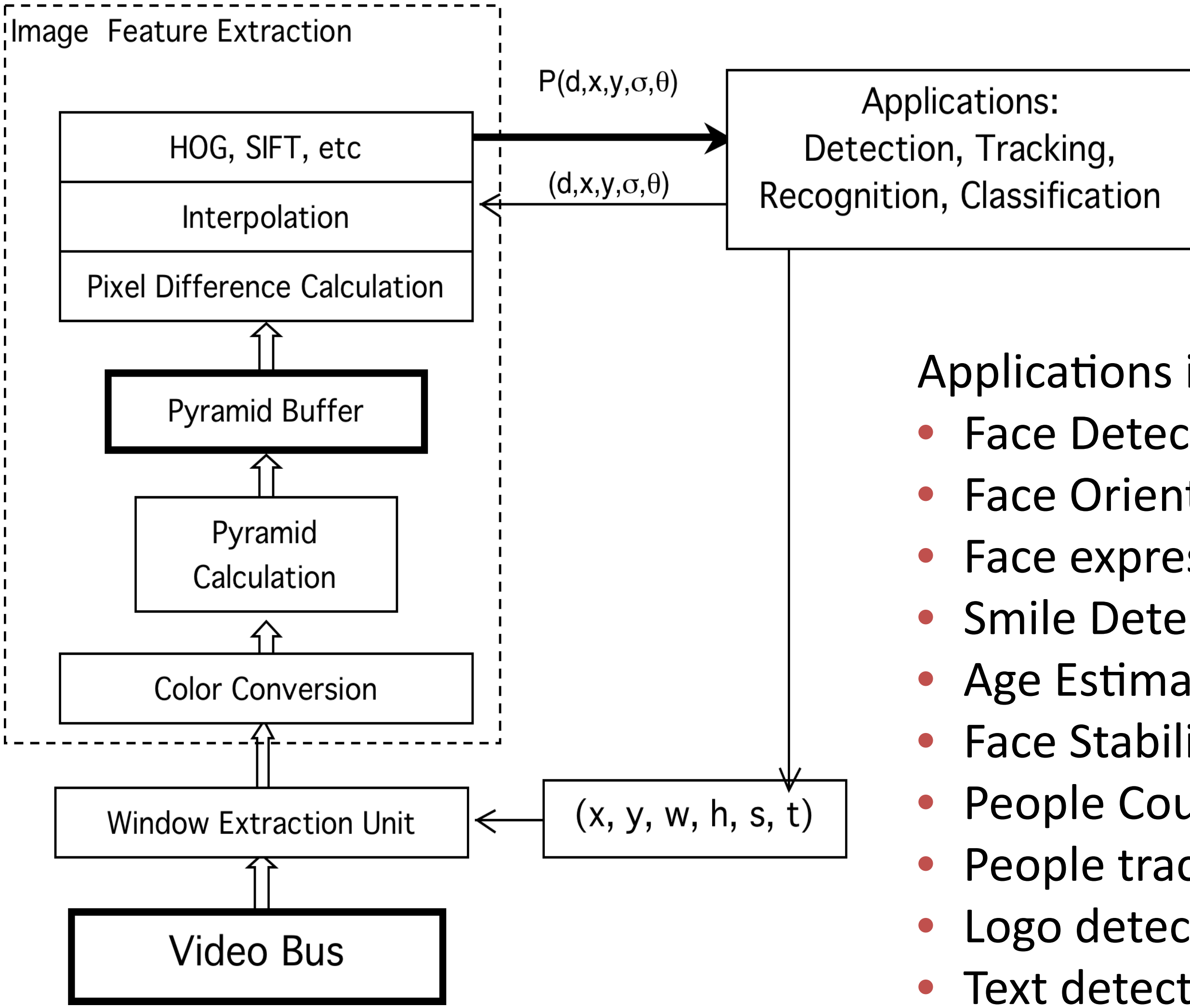
<u>Cognition</u>:
Slow, Deliberative, Creative

Enables planning, explanation, prediction and understanding.

Kahneman's System 2?

Kahneman D, Egan P. *Thinking, fast and slow*. New York: Farrar, Straus and Giroux; 2011

Prima CV (2012)
Real Time Vision Library for Mobile Devices



Applications include:

- Face Detection and tracking
- Face Orientation
- Face expression recognition
- Smile Detection
- Age Estimation
- Face Stabilization
- People Counting
- People tracking
- Logo detection and recognition
- Text detection

PRIMA CV
Real Time Vision Library for Mobile Devices

PrimaCV: Real time vision library for mobile devices

- Created in 2010 by Remi Barraquand, with contributions from Claudine Combe, John Ruiz, Varun Jain and many others
- Included Face detection, face orientation, posture, etc.
- Licensed to Novay 2012
- Used in several ICT Labs projects
- License Negotiations with Philips Research

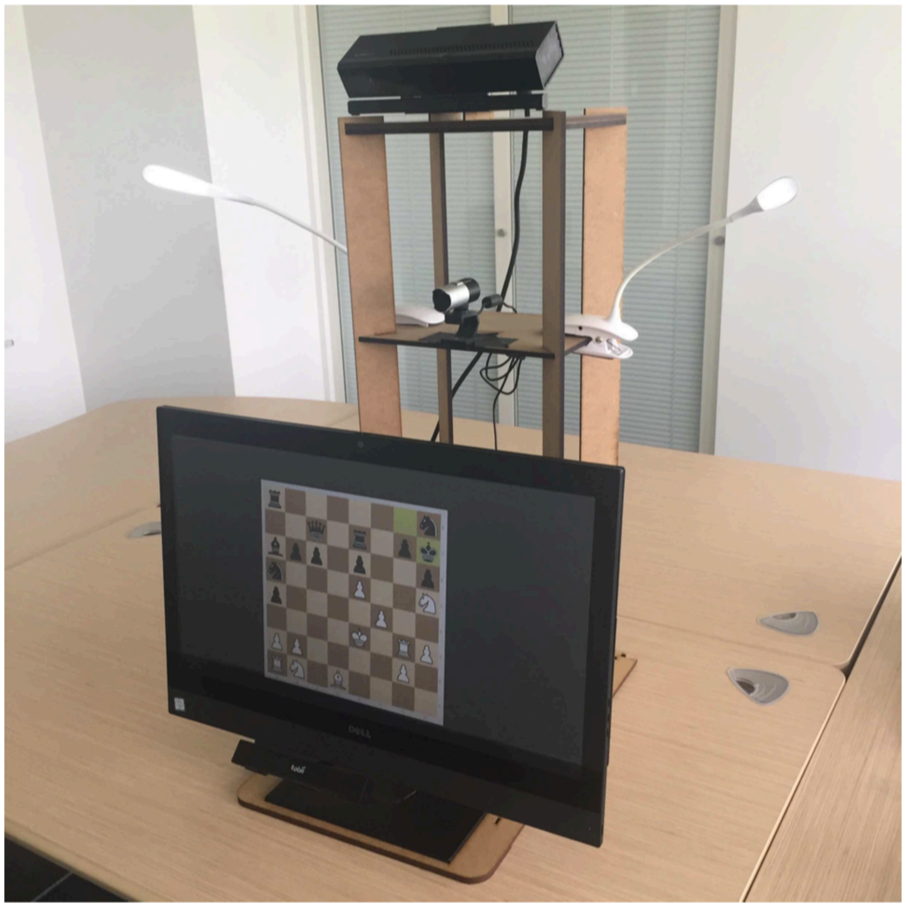
Our original intention was to maintain and improve PrimaCV in CEEGE

Between proposal submission (Nov 2014) and project scientific start (Oct 2016):

- PRIMA CV authors (doc, post-doc, eng) left Inria
- Several mature commercial products and open source libraries for measuring emotions arrived on the market.

Decision: Pivot Q1 to evaluating existing open source and commercial solutions.
Focus resources on modeling emotion and cognition in chess.

CEEGE Grenoble Research Instrument



<u>Sensors</u>:

- Interactive Touch-Screen (Windows)
- Kinect 2.0
- HD Webcam 1080p
- Eyetracker bar (Tobii & Fovio)
- Intensity light control

<u>Software</u>:

- Open Pose (body skeleton)
- Open Face (Emotions)
- Eye-works Fixation, pupil dilation)
- RGBD Sync – In-house synchronous Multimodal recording

Observing Fixation and Attention with a Remote Eye-Tracker

Remote Eye Trackers (Tobii, Fovio) provide real time tracking of gaze and fixation.

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lichess.org
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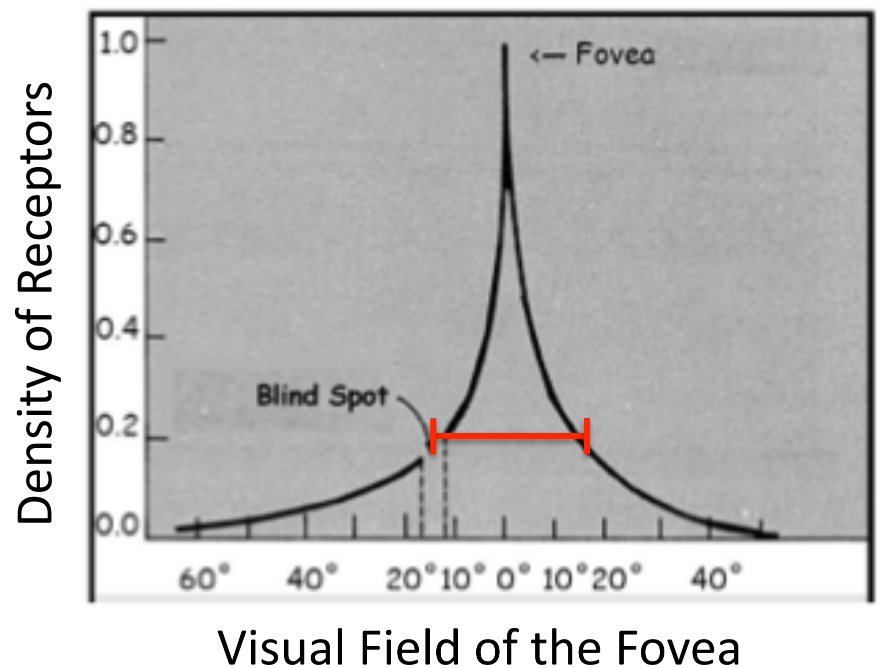
The CEEGE Instrument:



System designed so that the visual field of the Fovea corresponds to a chess square.

Body Posture: Kinect, Open Pose

FACS: Facial Action Coding System

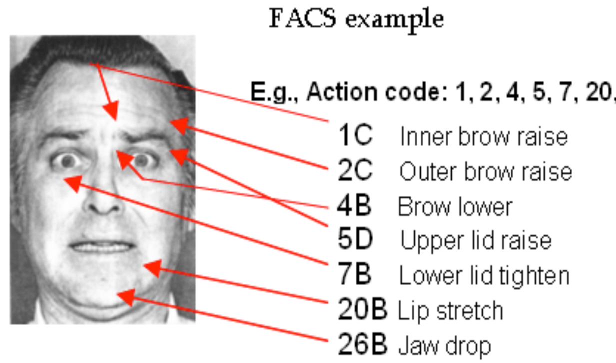


Image provided by UCSD Machine Perception Lab

Facial Action Coding System (FACS) : A system to label human facial expressions, developed by P. Ekman and W. V. Friesen, 1978)

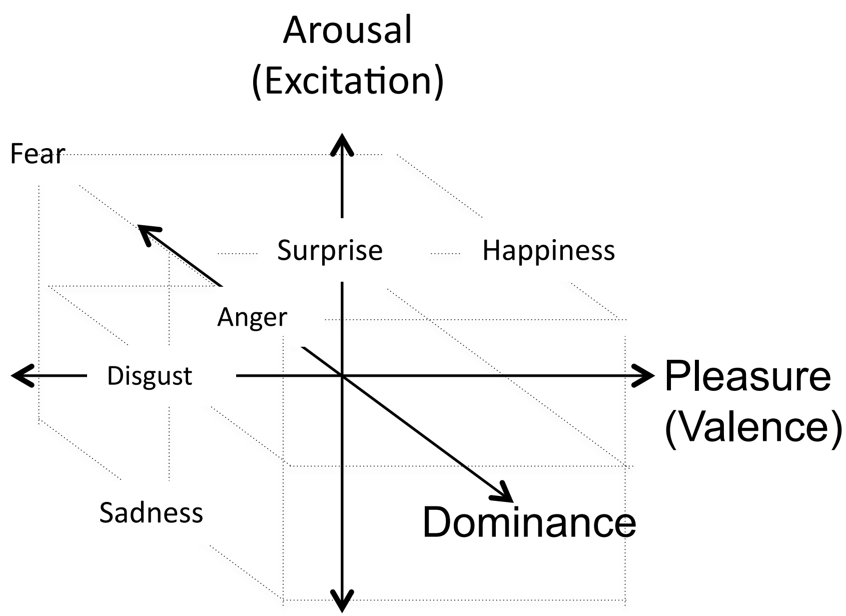
A common standard for recognizing facial expression of emotions

Available in several commercial and Open Source software Packages.

Ekman's Six Basic Emotions

Emotion	Action Units
Happiness	6+12
Sadness	1+4+15
Surprise	1+2+5B+26
Fear	1+2+4+5+20+26
Anger	4+5+7+23
Disgust	9+15+16

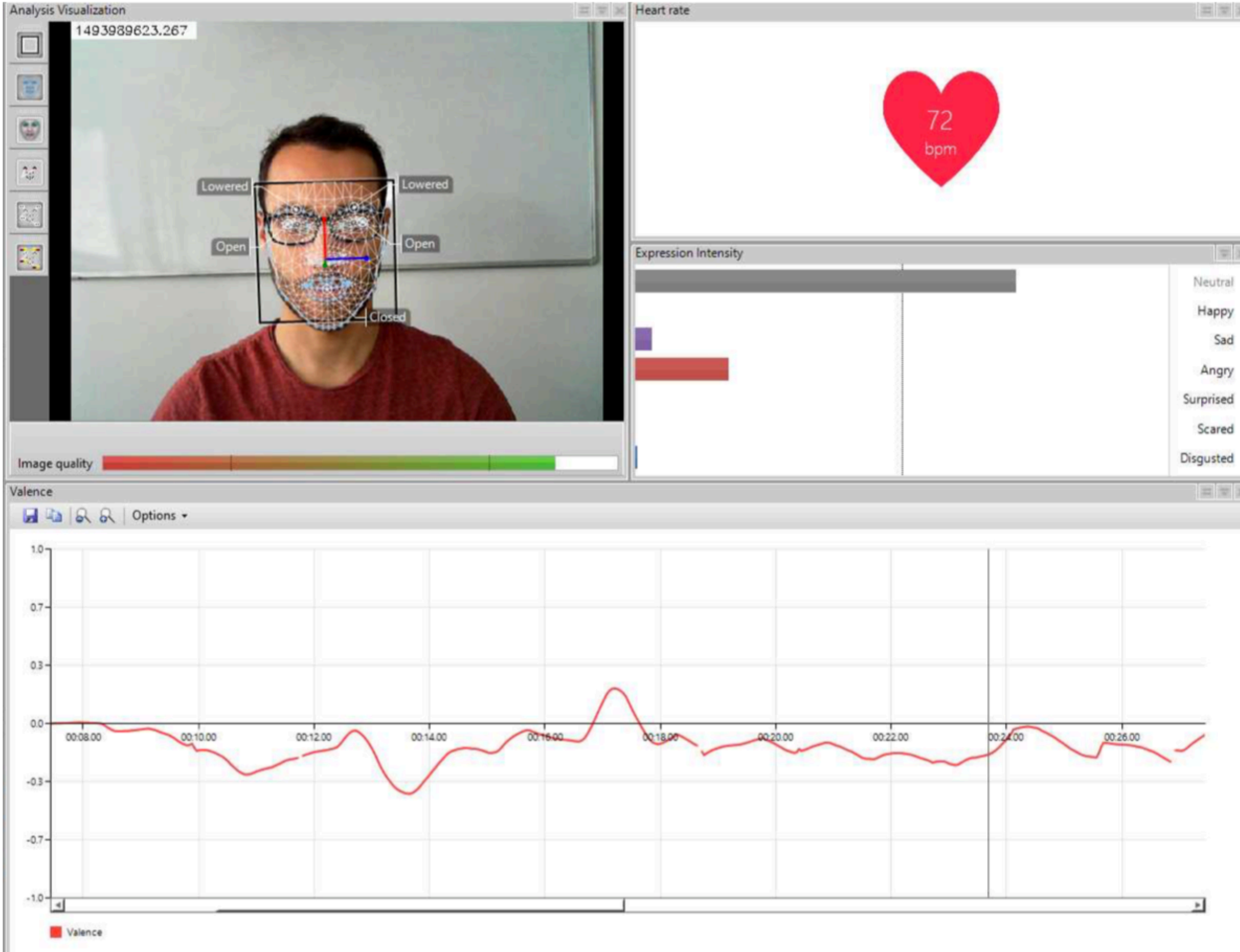
The PAD Model for Emotions



The PAD (Pleasure, Arousal, Dominance) model

1) Pleasure – Displeasure: Valence of an emotion
2) Arousal – Calm: Intensity, physiological excitation
3) Dominance – Submissive: Disposition to assert control.

J. A. Russell , A. Mehrabian, "Evidence for a three-factor theory of emotions", Journal of Research in Personality Vol. 11(3), pp 273-294, Sept 1977.


Analysis Visualization
1493989623.267
Lowered
Lowered
Open
Open
Closed
Image quality
Heart rate
72
bpm
Expression Intensity
Neutral
Happy
Sad
Angry
Surprised
Scared
Disgusted
Valence
Options
1.0
0.7
0.3
0.0
-0.3
-0.7
-1.0
00:08.00
00:10.00
00:12.00
00:14.00
00:16.00
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00:20.00
00:22.00
00:24.00
00:26.00
Valence

Fixation and attention

Fixation can be used to measure attention and to predict next move.
But what does this tell us about comprehension of the player?

J. Le Leoudec, T. Guntz, D. Vaufreydaz and J. L. Crowley, Deep Learning Investigation for chess player attention, prediction using eye-tracking, and game data, 2019 ACM Symposium on Eye Tracking Research & Applications, ETRA'2019, Denver, Colorado.

Pilot Study – First experiment – March 2017

Objectives:

1. Verify experimental equipment
2. Verify that eye-gaze and emotion correlate to expertise.

Task: 6 time limited tasks of increasing difficulty (Mate in N).

Measurements:

Eye-gaze (Tobii remote), posture (Kinect), Ekman 7 Emotions (Face Reader).

Hypothesis:

- Players would display concentration during problem solving, frustration if unable to solve problem, and pleasure when finding problem solution

Experiments:

Session 1: 21 subjects (14 recordings usable)
Session 2: 9 subjects (8 recording usable).

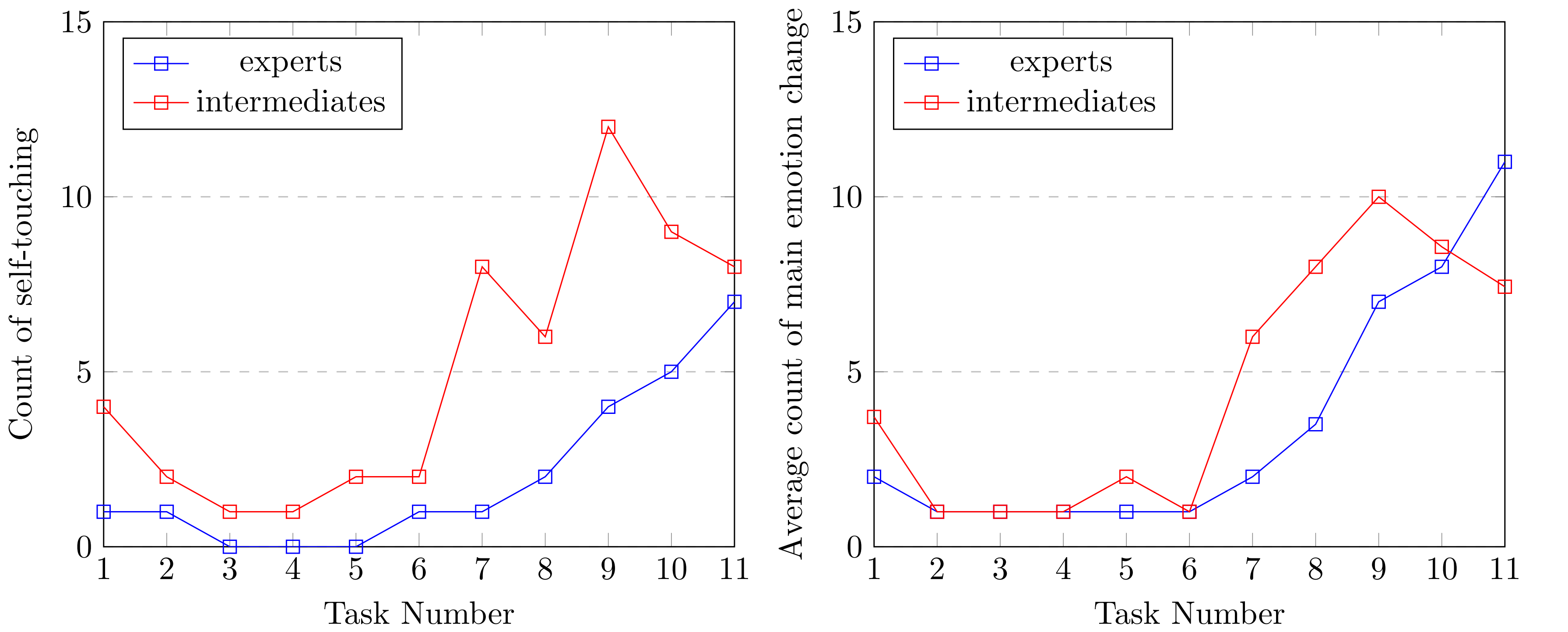
Pilot Study – First experiment – Mar 2017

Results:

1) 22 useful recordings (9 expert, 13 Intermediate).
2) Surprising result: Self touching and rate of change of emotion state increased from a neutral during reactive play for easy problems to frequent touching and rapid changes in emotion as the problems became more challenging.

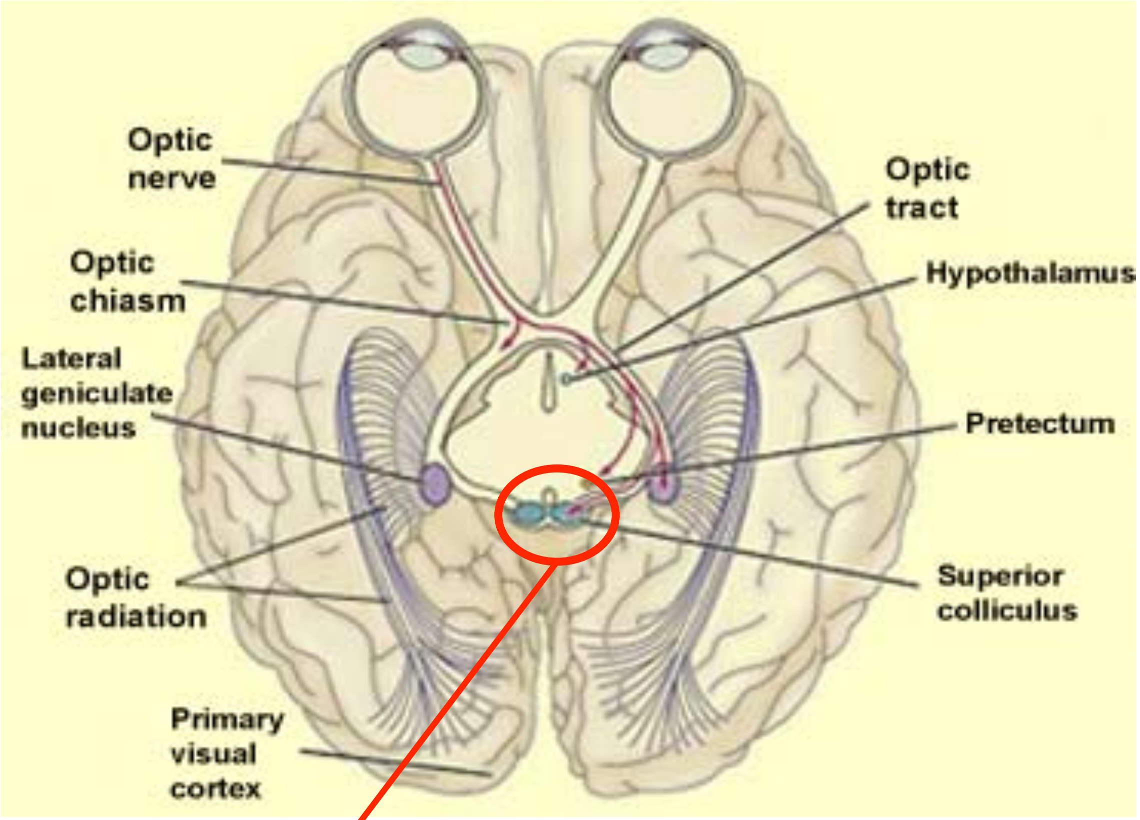
WHY !?

Physiological reaction to problem difficulty



Number of self-touches (left) and number of changes in emotion (right) for intermediates and experts engaged in solving the 11 problems.

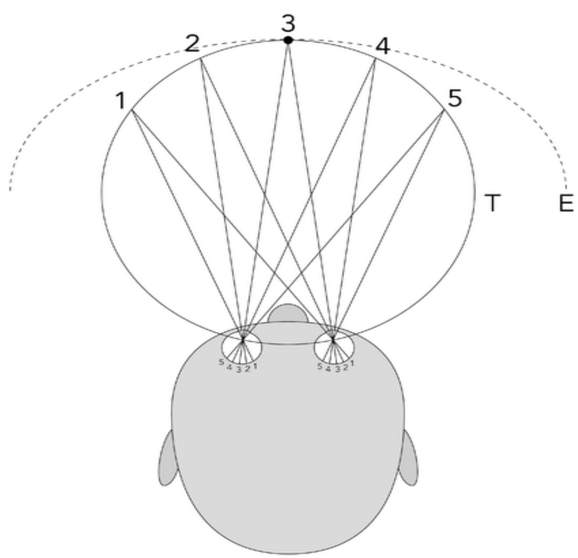
The Physiology of Fixation and Attention

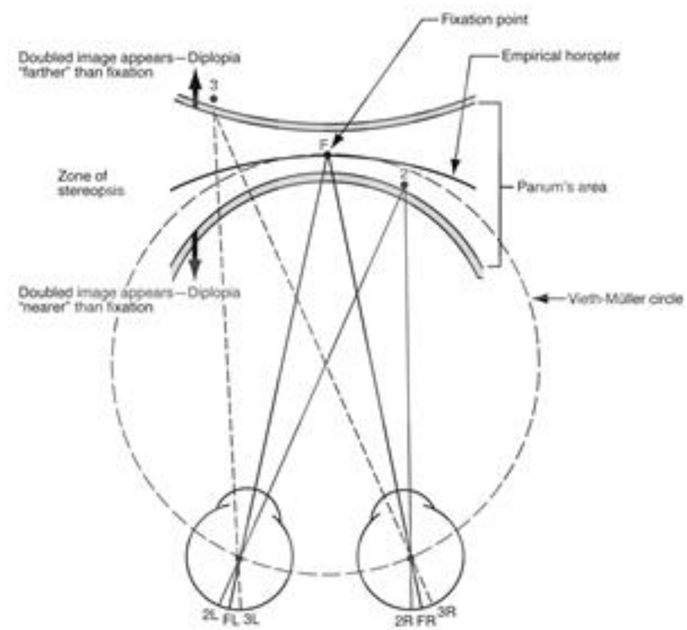


Superior Colliculus:

- 7 Layer filter with input different brain regions
- Controls vergence, version and cyclotorsion.

The Superior Colliculus Controls the Horopter



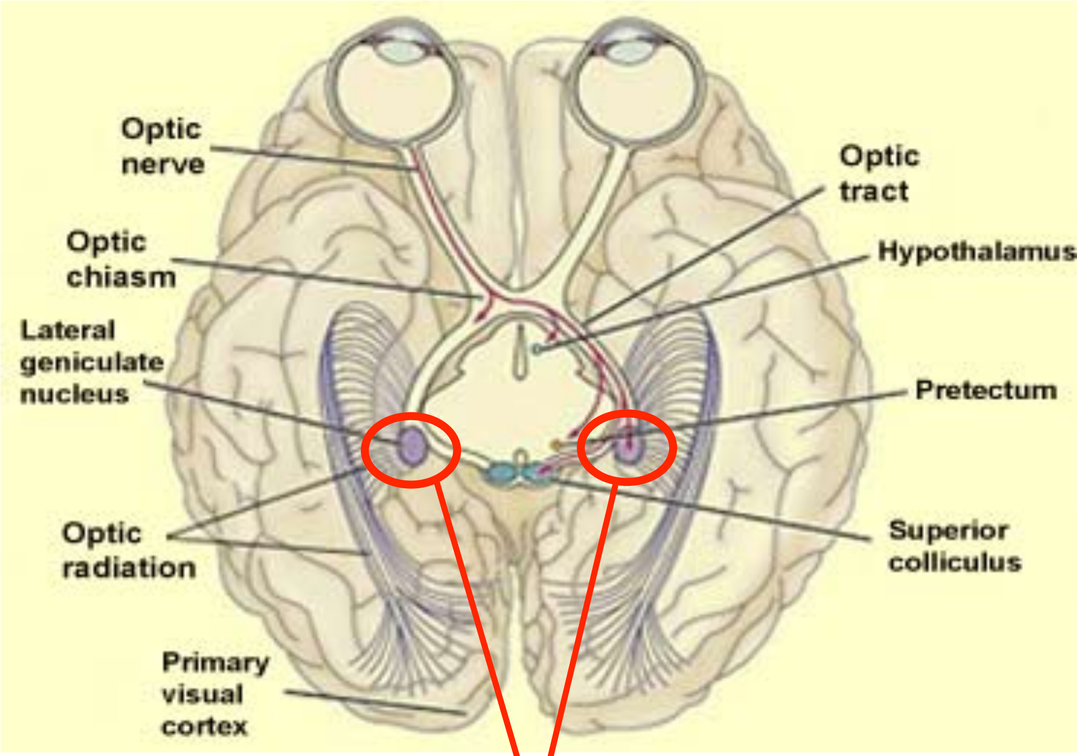


The Horopter: The Locus of Fixation.

Points in space that project to the same position in both retina.

Visual stimuli outside the horopoter are un-attended.

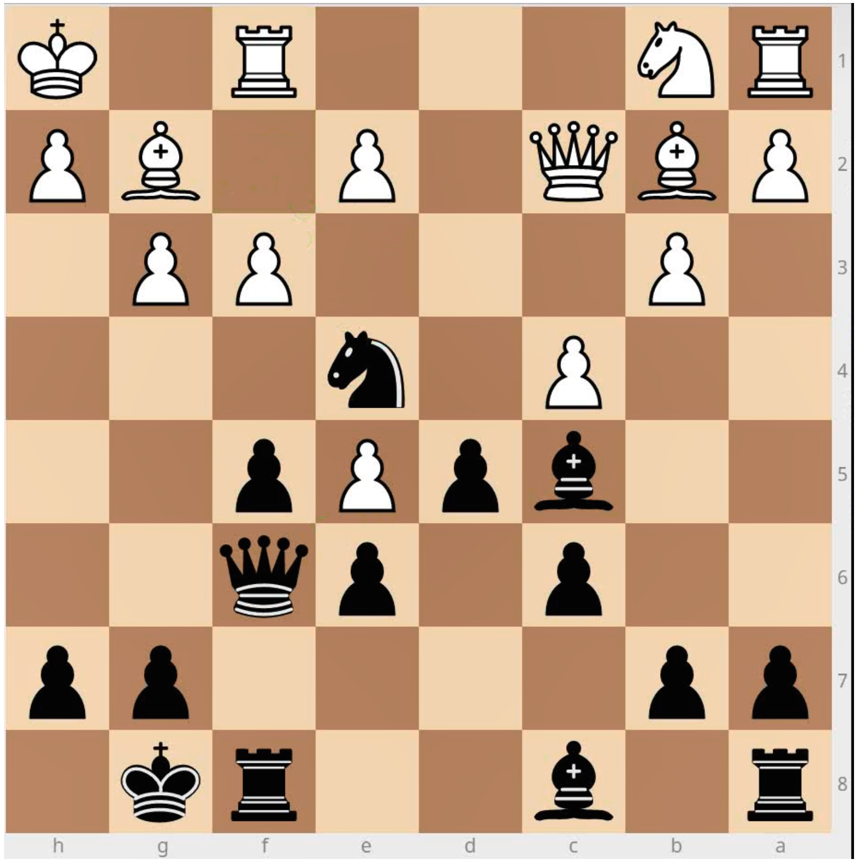
The Physiology of Fixation and Attention



Lateral Geniculate Nucleus (LGN).

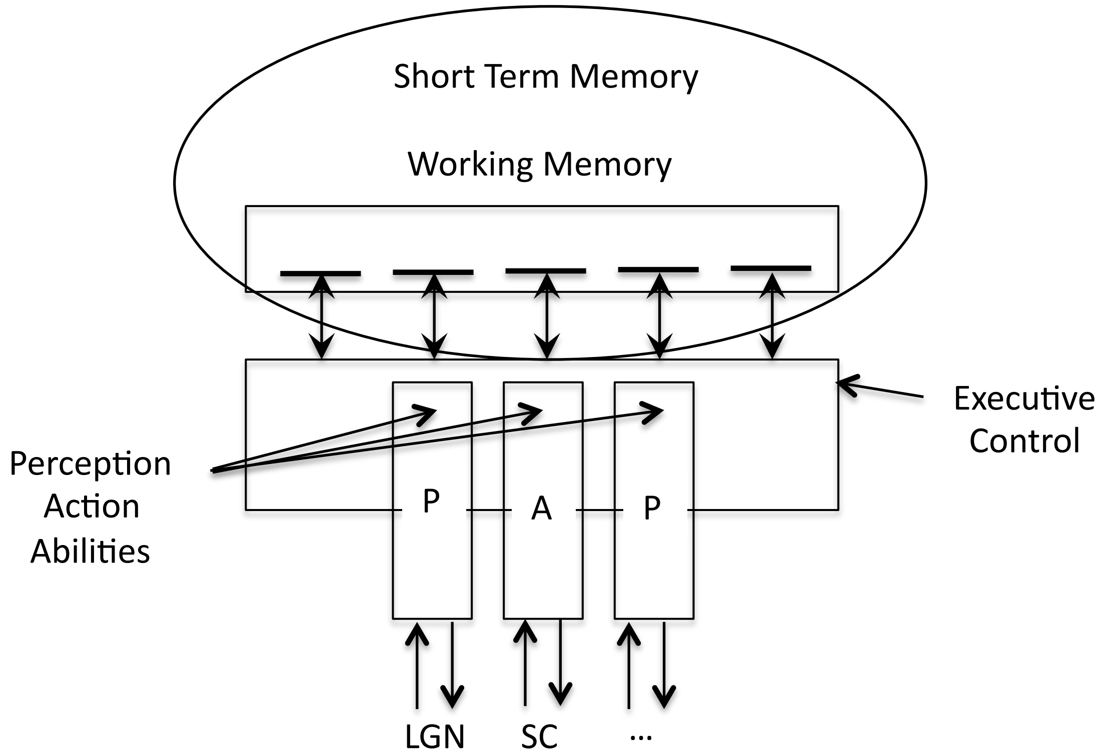
- Filter for Attention: The LGN Suppresses non-attended visual information
- The LGN relays a filtered retinotopic map to the visual cortex.

The Physiology of Fixation and Attention



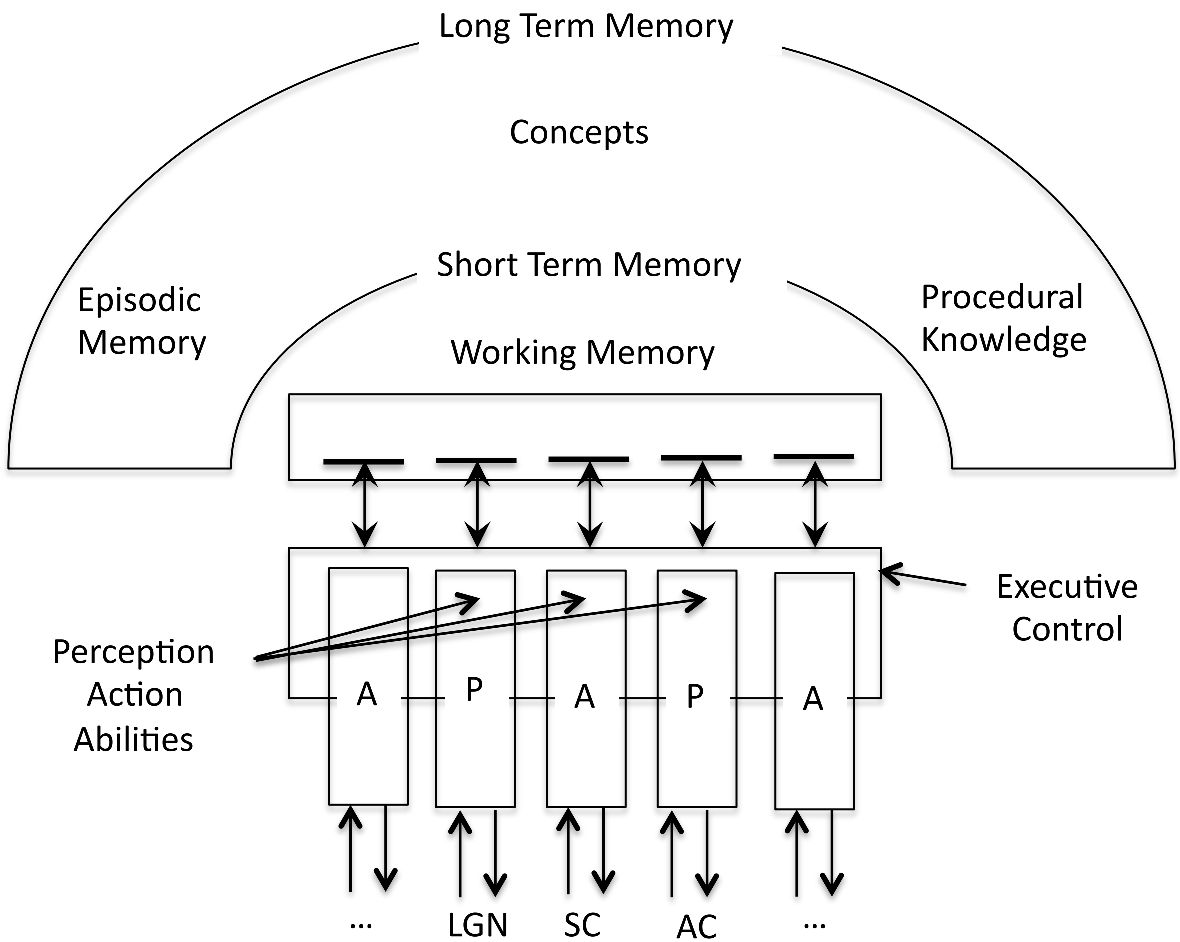
The LGN suppresses visual information

Cognition is limited by Working Memory



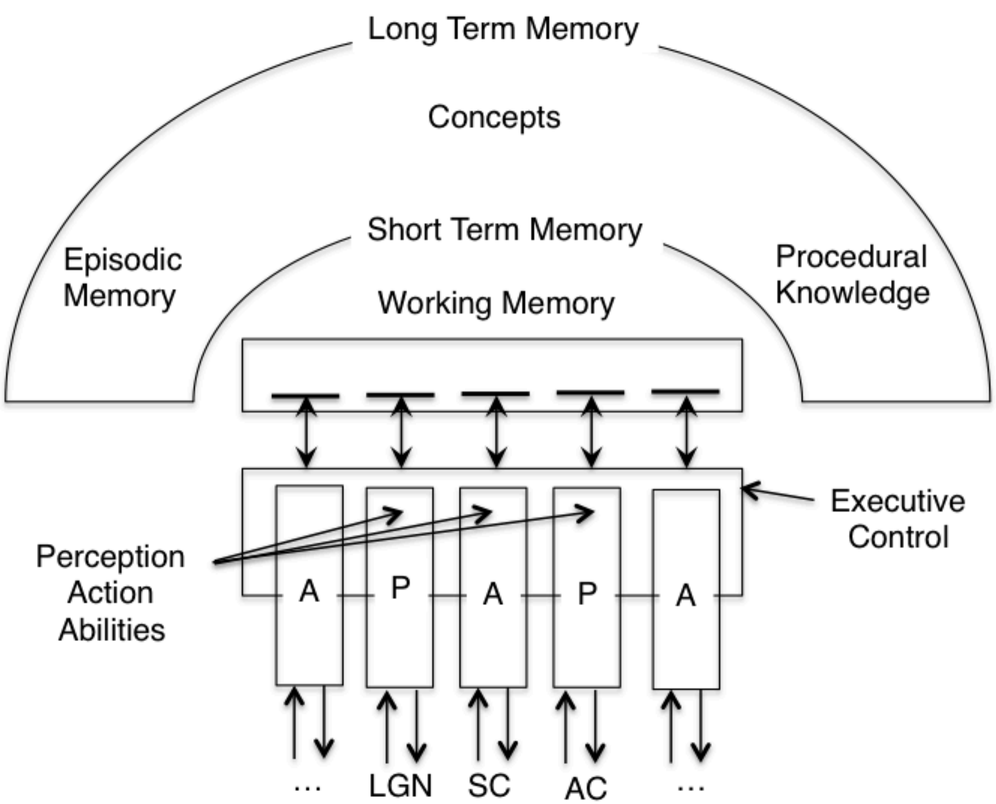
G. A. Miller, The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, *63*(2), 81-97, 1956.

Working Memory (WM) associates perception with Long Term Memory (LTM) and Short Term Memory (STM)



N. Cowan, Working memory underpins cognitive development, learning, and education. *Educational Psychology Review*, *26*(2), 197–223, 2014

WM associates perception with STM and LTM



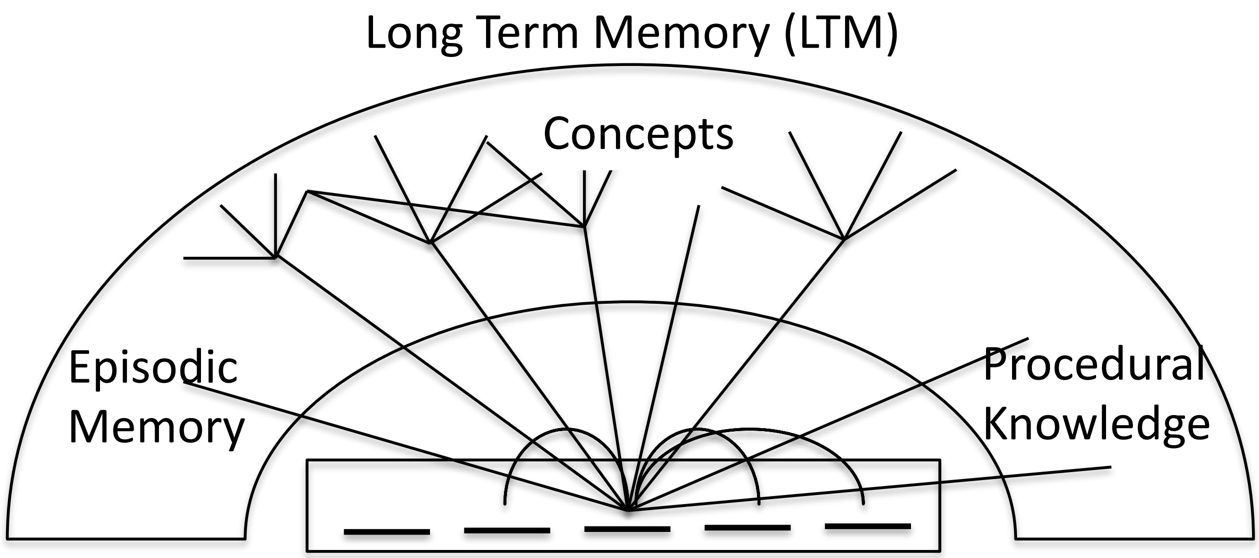
Working memory elements are called "entities".

WM entities represent perceived or recalled phenomena.

Entities can be associated with
- Perception and action
- Episodic memories
- Concepts
- Procedural knowledge
- Reasoning Knowledge
- Other forms of memory

W. Kintsch, *Comprehension: A paradigm for cognition*, Cambridge university press, 1998.

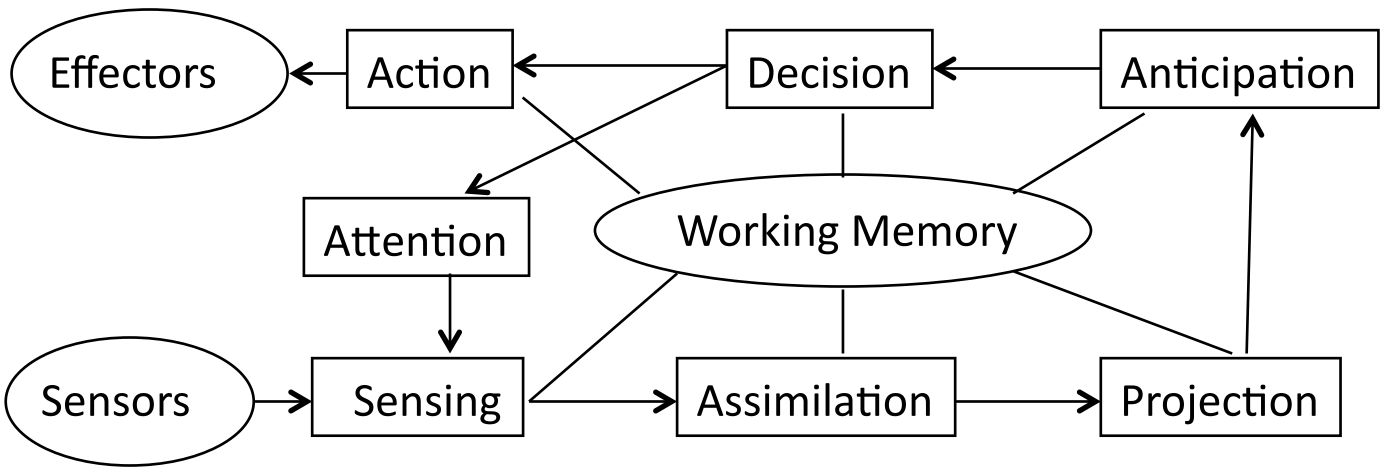
Spreading Activation from WM to LTM



Hebbian model for association of entities from working memory with concepts, Procedural knowledge, Episodic memory in Long Term Memory Association

J. R. Anderson, A spreading activation theory of memory, Journal of Verbal Learning and Verbal Behavior, Volume 22, Issue 3, Pages 261-295, June 1983

Reasoning with working Memory



<u>Assimilation</u>: interpretation for entities, relations and events
<u>Projection</u>: Transition probabilities for possible next situations
<u>Implication</u>: Possible outcomes of actions
<u>Decision</u>: Appropriateness or inappropriateness of actions.
<u>Attention</u>: Relevant entities and properties to perceive

M. R. Endsley, Toward a theory of situation awareness in dynamic systems. *Human factors*, *37*(1), 32-64.1995.

An Information Processing Model for Comprehension in Chess

Concepts: Mental constructs generalized from particular instances.

Concepts model the basic elements of cognition.
Concepts are modeled with Frames.

Frames: Abstract schema for concepts.

Schema for a Frame:

- A unique ID
- A name (optional)
- A set of relations to other concepts
- Meanings: episodic memories
- Roles: Actions that are enabled or prevented by the concept.

M. Minsky, (1975) A Framework for Representing Knowledge, in: Patrick Henry Winston (ed.), The Psychology of Computer Vision. McGraw-Hill, New York), 1975.

Concept Frames for Chess Entities

Frames provides schema for representing concepts as entities in WM.

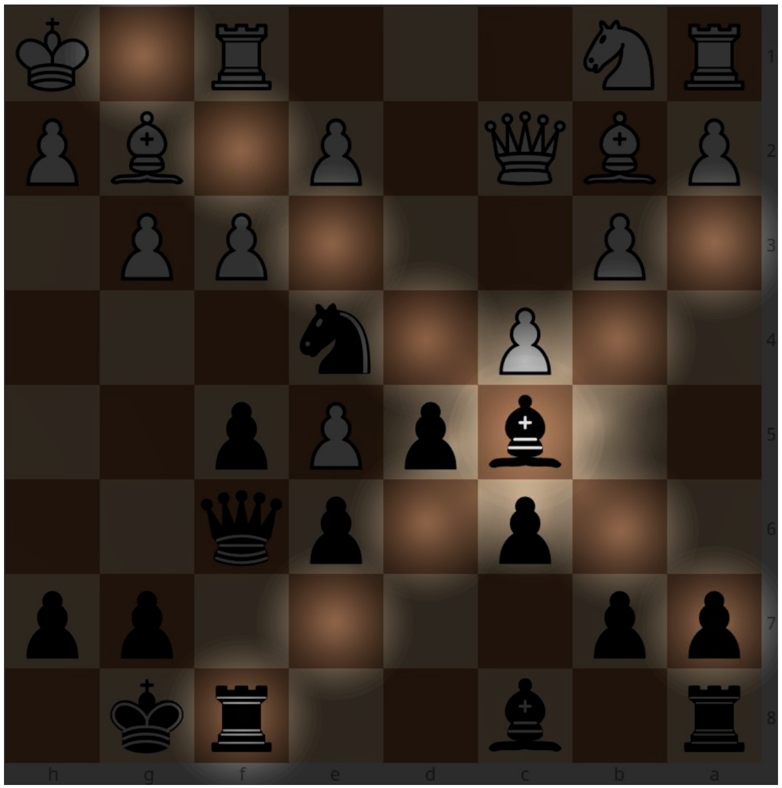
Slots of a Frame encode relations between entities and Long Term memory (relations in a frame are internal and immutable)

Example: Concept Frame for a Chess piece.

(ChessPiece (piece-ID)
    (kind (one-of (king, queen, bishop, knight, rook, pawn)))
    (color (one-of (black white)))
    (position (rank, file))
    (actions (move-procedures()))
    (span (squares in range)
)

F. Gobet, and H Simon, (1998). Expert chess memory: Revisiting the chunking hypothesis. *Memory*, *6*, 225-255, 1998

Evidence for Awareness from Fixation



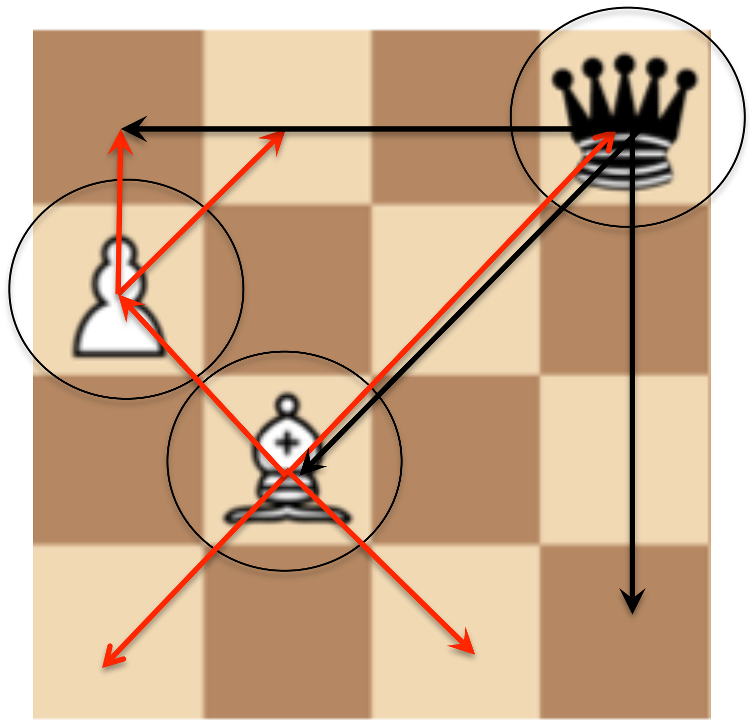
The Span for a piece P_k is the set of all squares that are within range of the piece : $\{S\}_k$

Fixation anywhere in the span is evidence for awareness.

Span for a Chess Piece

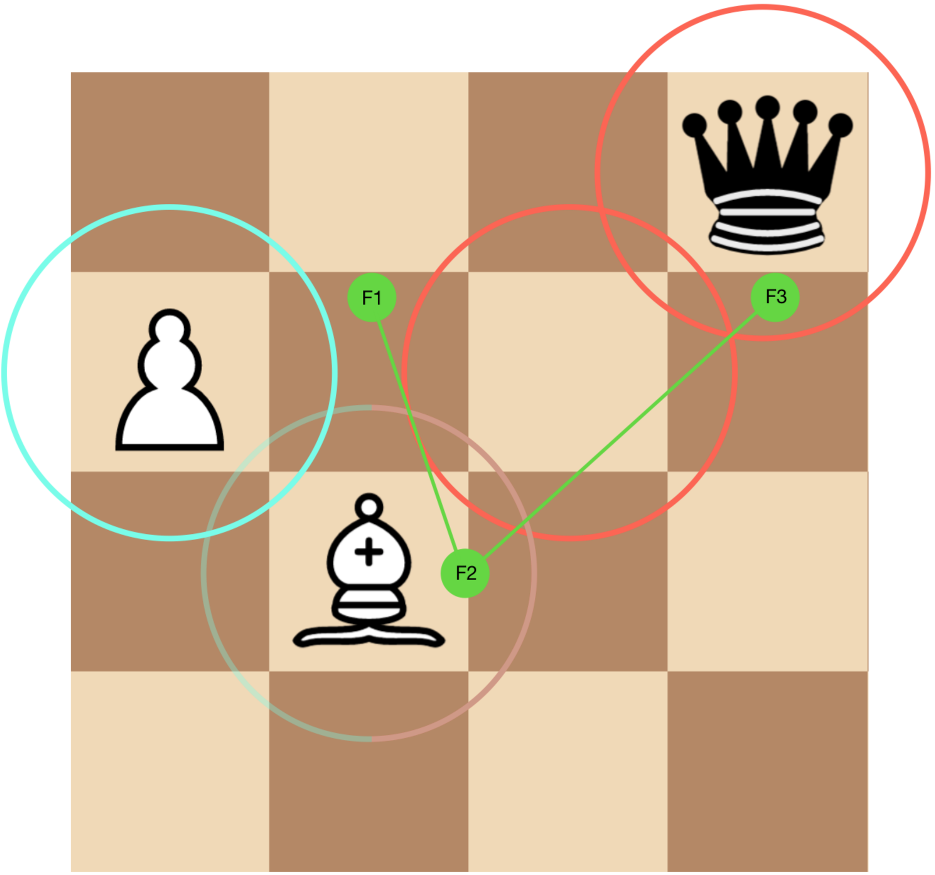
Chess Chunks for individual pieces include "Span" (set of squares) that are accessible from the piece.

(Piece (WP)
(activation (A))
(kind (pawn))
(color (White))
(Position (P))
(Actions(…))
(Span {S})
)
(Piece (WB)
(activation (A))
(kind (bishop))
(color (White))
(Position (S))
(Actions(…))
(Span {S})
)



(Piece (BQ)
(activation (A))
(kind (queen))
(color (Black))
(Position (P)
(Actions (…))
(Span {S})
)

Evidence for Awareness from Fixation



Activation Energy for chunks:
(number of chunks that include F_j in span)

$$A(C_k \mid F_j) = \frac{1}{\#(F_j \in \{S\}_k)}$$

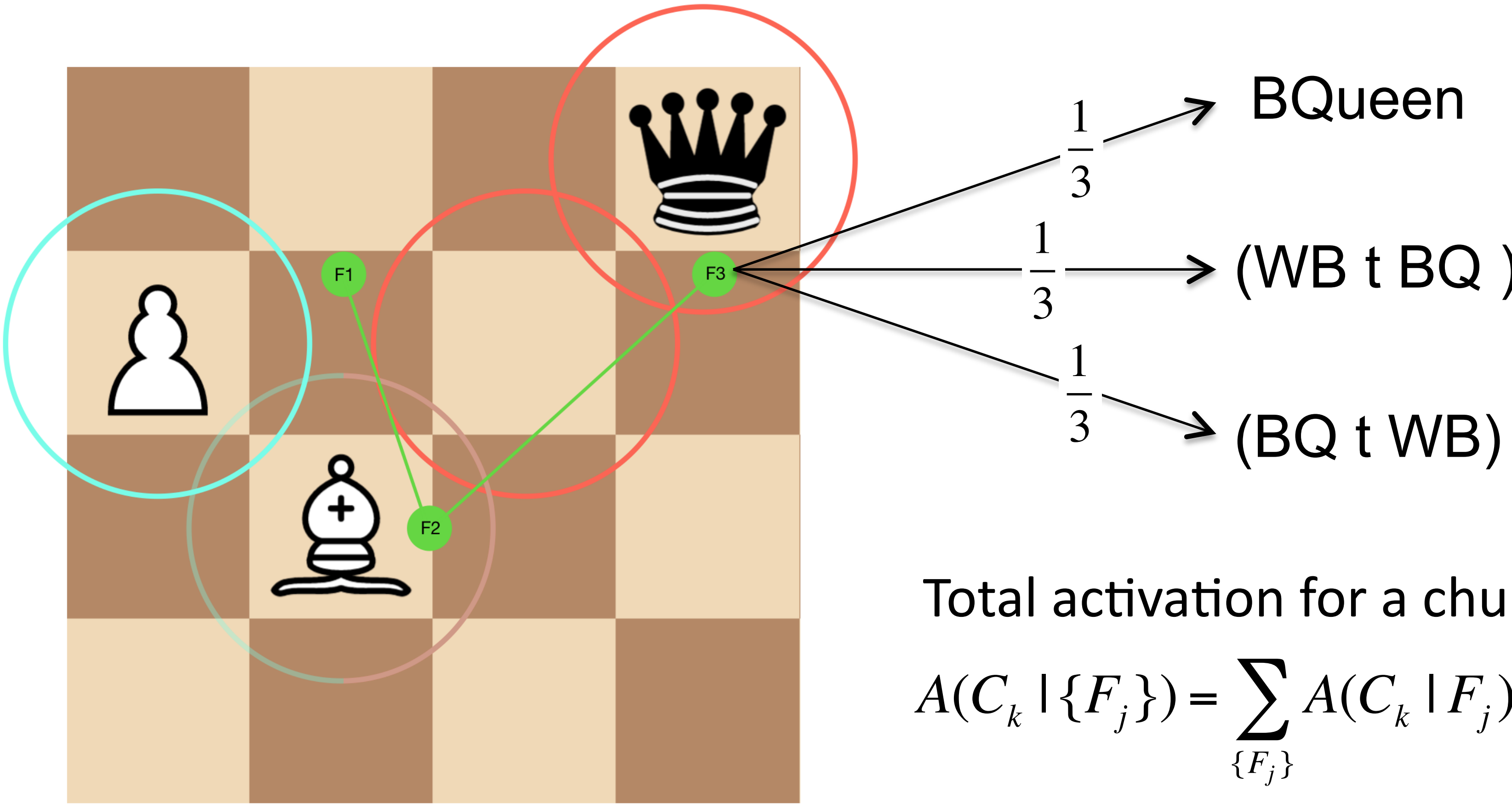
Total activation for a chunk:

$$A(C_k \mid \{F_j\}) = \sum_{\{F_j\}} A(C_k \mid F_j)$$

Evidence for Awareness from Fixation

Activation energy for entities:
(number of chunks that include F_j in span)

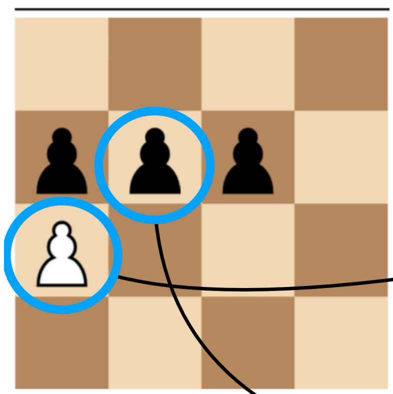
$$A(C_k \mid F_j) = \frac{1}{\#(F_j \in \{S\}_k)}$$



Total activation for a chunk:

$$A(C_k \mid \{F_j\}) = \sum_{\{F_j\}} A(C_k \mid F_j)$$

Beginners reason with pieces



a) wall of pawns

(ChessPiece (P1)
    (kind (pawn))
    (color (white))
    (position (A ; 4))
    (actions (pawn_moves …))
)

(ChessPiece (P2) (. . .))

(ChessPiece (P3) (. . .))

(ChessPiece (P4) (. . .))

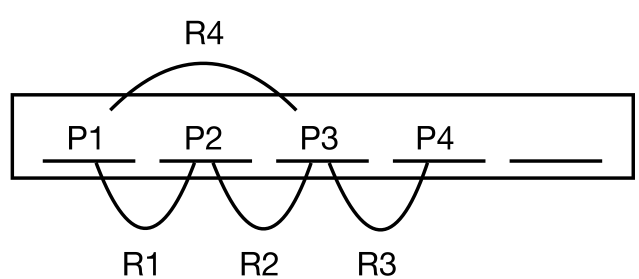
(Relation (R1)
    (Name (Threatened))
    (Kind (offensive))
    (Subject (P1))
    (Object (P2))
)

(Relation (R2) (. . .))

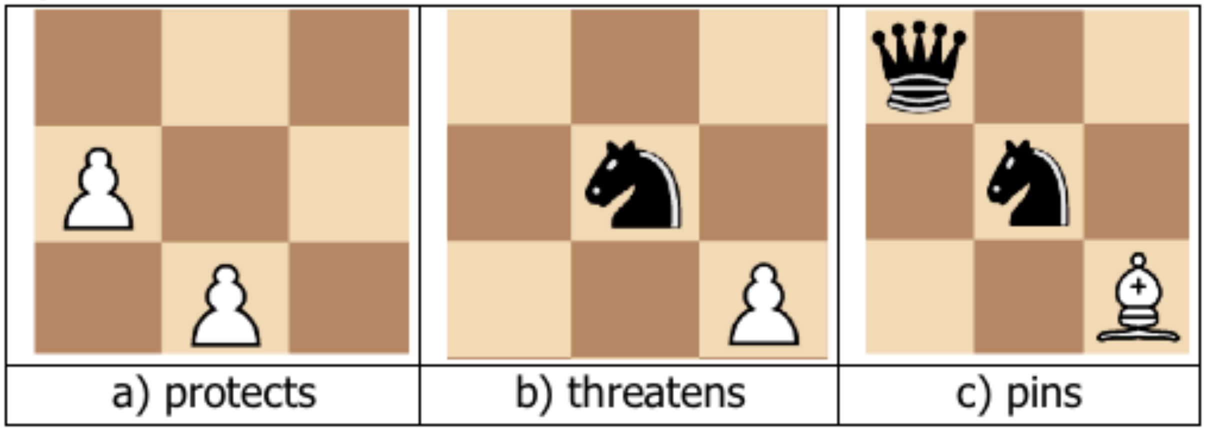
(Relation (R3) (. . .))

(Relation (R4) (. . .))

Working Memory:



Experts reason with chunks.



Chess chunks are concepts for configurations of pieces, or configurations of simpler chunks. Chunks are composed hierarchically.

Chess chunks associate configurations with actions, roles, and meanings.

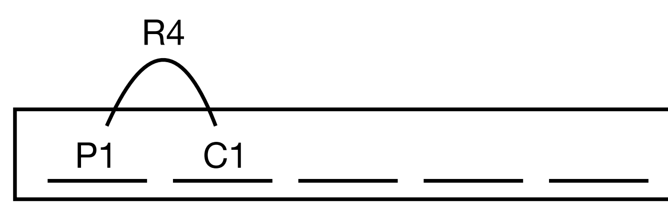
Examples:

a) Protects (WP1, WP2)

b) Threatens (WP1, BK1)

c) Pins(WB1, BQ, BK1)

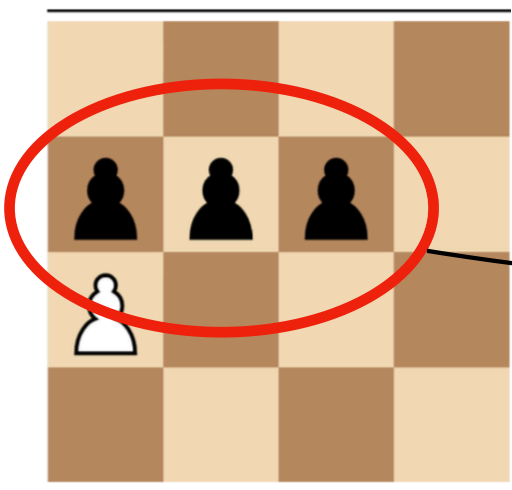
Working Memory:



Chess Chunks: Compound Concepts

Chunks reduce WM load by replacing several entities with a single compound entity.

Experts reason with several thousand chunks.

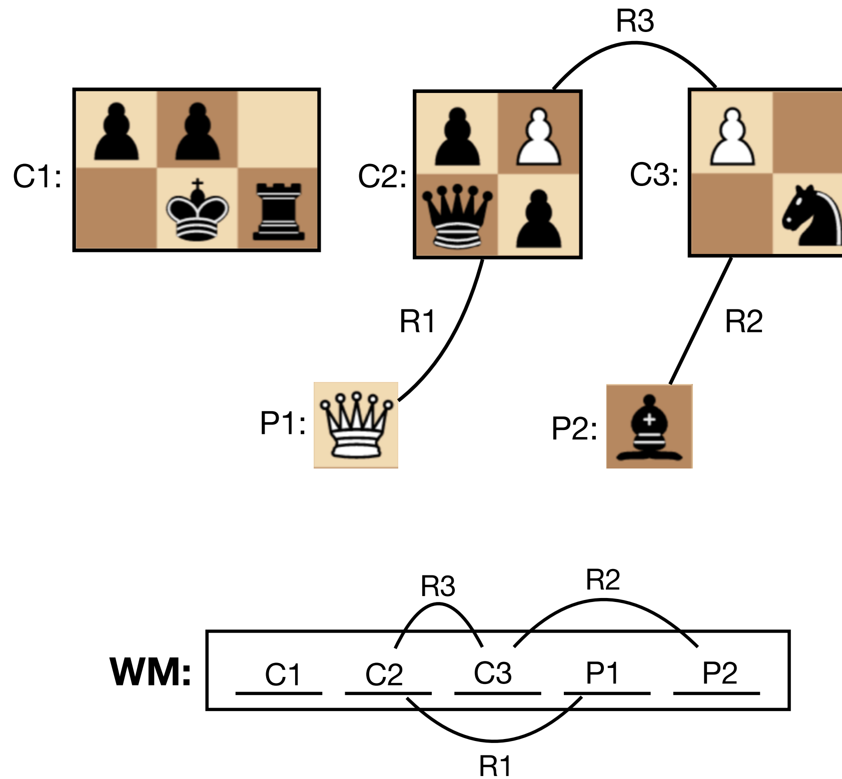


(Concept Wall-of-Pawns
    (Color (black, white))
    (Kind (Defensive))
    (Composed of (list-of (Pawns))
    (Position (row)
    (Relations (Beside(P1, P2), (Beside(P2, P3))
    (Roles (blocks (opponent pawns), screens (own pieces))
)

R4

Working Memory: P1 C1

Despite Chunking, WM is rapidly over-loaded

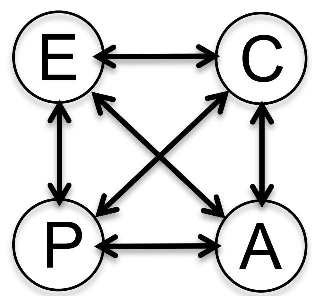


Emotion and Cognition:
Two Complementary Intentional Systems

<u>Emotion</u>:
Fast, Reactive, Predictable.

Enables rapid reaction to threats and opportunities.

Kahneman's System 1?



<u>Cognition</u>:
Slow, Deliberative, Creative

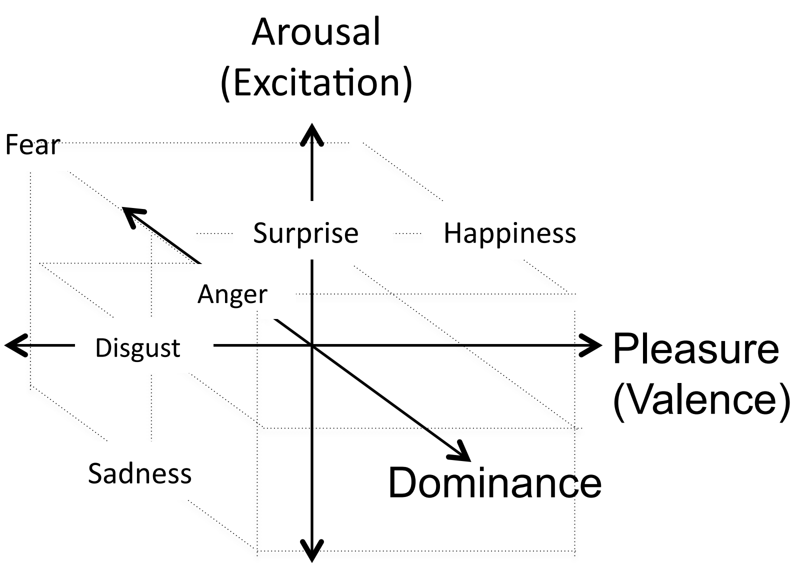
Enables planning, explanation, prediction and understanding.

Kahneman's System 2?

Kahneman D, Egan P. *Thinking, fast and slow*. New York: Farrar, Straus and Giroux; 2011

Emotions substitute experience for reason

Emotions are displayed by physiological signals.
We believe that emotions are reactions to past experience with concepts (chess chunks) and with situations.



PAD model (Pleasure, Arousal, Dominance)

<u>Hypothesis</u>:
Pleasure, Arousal and Dominance are associated with concepts by experience

For any situation, (P, A, D) express:

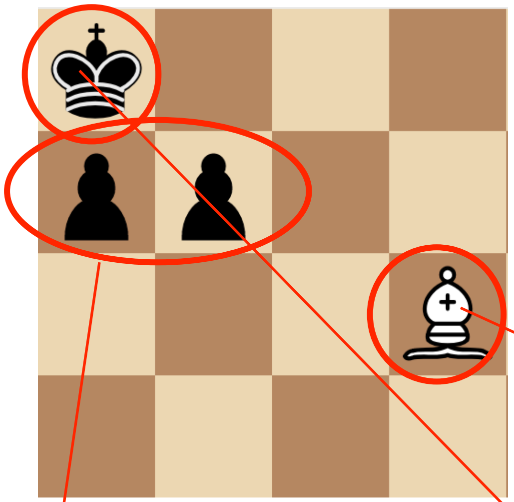
Pleasure: Frequency of positive (or negative) outcomes

Arousal: Imminence of opportunity or threat.

Dominance: Confidence in ability to control outcome.

Hypotheses:
Emotions drive selection of chunks

Players prefer chunks with high criticality (arousal), high valence (positive experience) and high dominance (confidence in outcome).



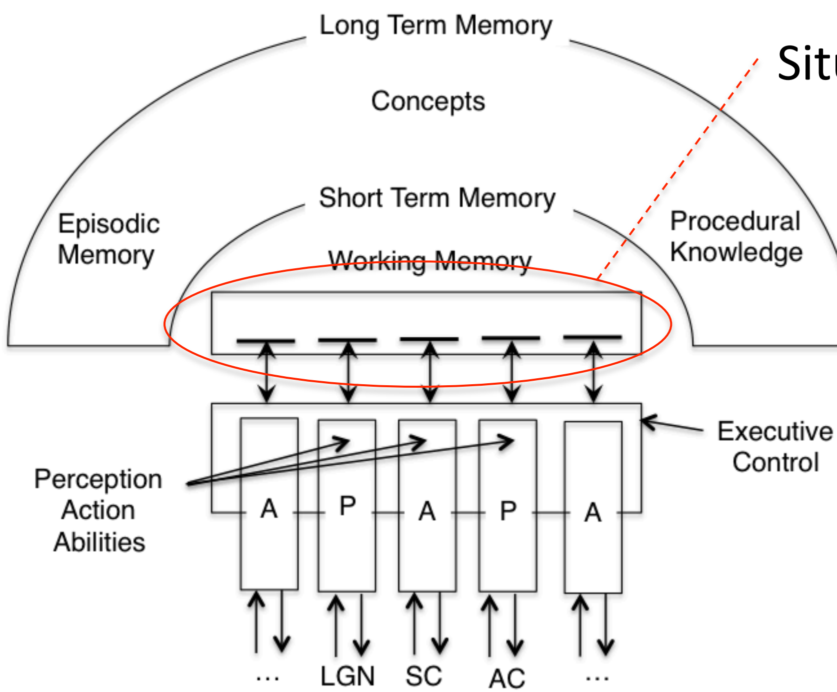
(Concept Trapped-King (BK)
    (Color (black))
    (Kind (Offensive))
    (Composed of (list-of (WB, BK, WP))
    (Blocks (move (BK, WP)))
    (Blocks (move (BK, WB)))
    (Emotion (P +), (A +), (D ++))
)

Wall of Pawns (WP)

Black King (BK)

White Bishop (WB)

Chess Situations: Relations between Chunks



Situation Model

A situation is a set of relations between entities. Relations are external to entities and changeable.

Situation Model schema:

```
(Situation (S-Name)
   (E1  entity-ID) (E2 Entity-ID)
   (R1 (Beside E1 E2))
   (R2 (meanings Episodic-Memory-ID))
   (R3 (Actions Action-ID))
   (Emotions (P) (A) (D))
)
```

Current research hypotheses:

1) Chunks are learned from frequently encountered situations.

2) Emotions (P, A, D) guide the selection chunks used to model the situation and the selection of situations for planning.

A Second Experiment

Protocol:

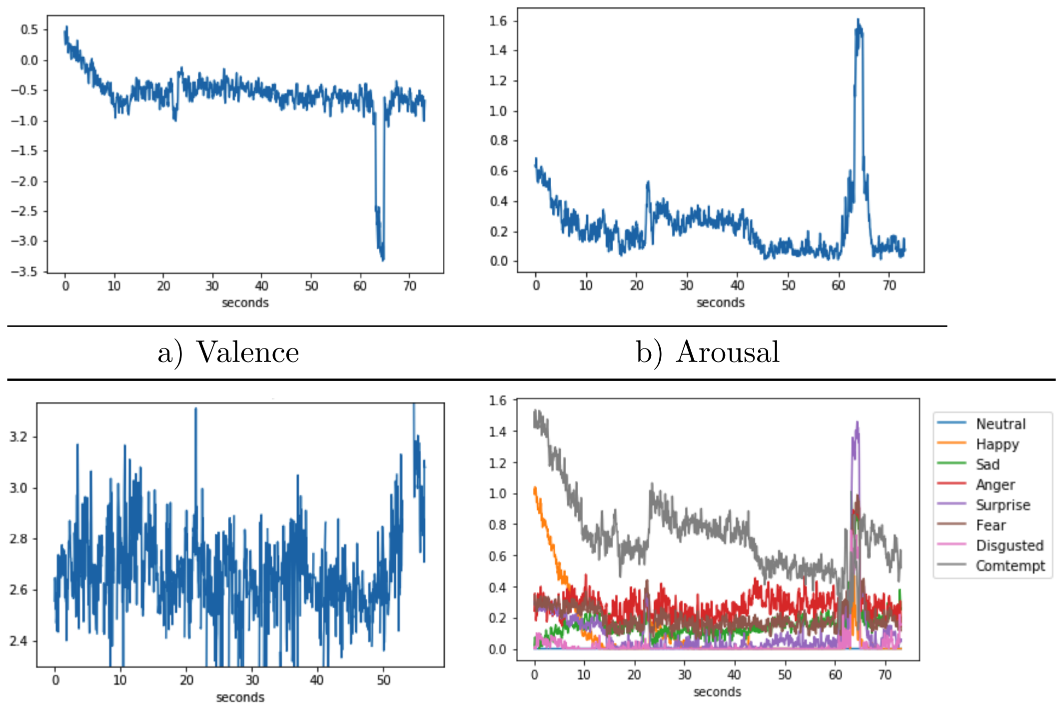
- 7 Tasks of increasing difficulty (4 Mate-in-N tasks and 3 survival tasks)
- Retroactive Task Explanation (RTE) after each task,

RTE: subject describes understanding of the problem situation.

23 subjects (2 expert, 19 intermediate, 2 beginners).
(Elo ranges 1930 to 2000 and 1197 to 1700).

Measurements: Eye-gaze (Fovio), pupil dilation, FACS, Ekman emotions (Open Face), Self Touches (Open Pose) .

S6 (Elo 1950), Task 8: An impossible survival task

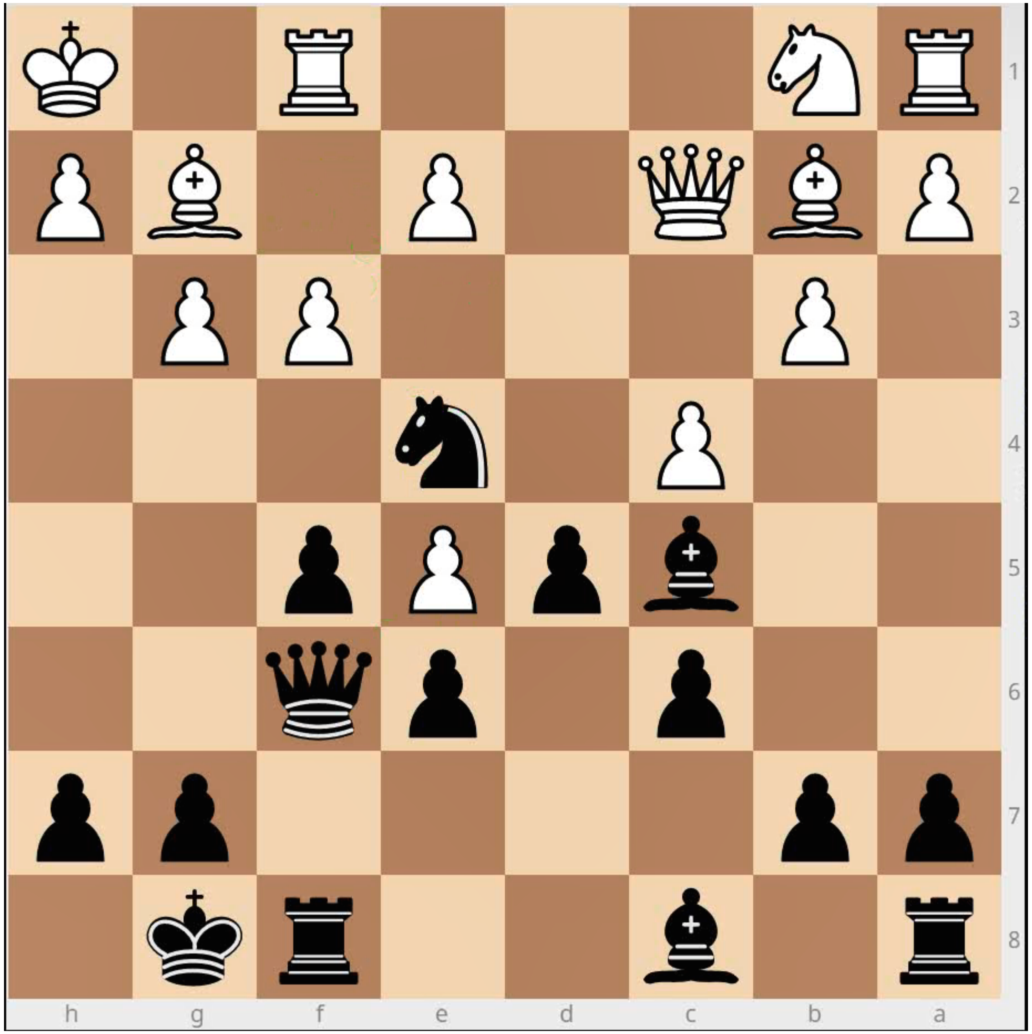


a) Valence b) Arousal

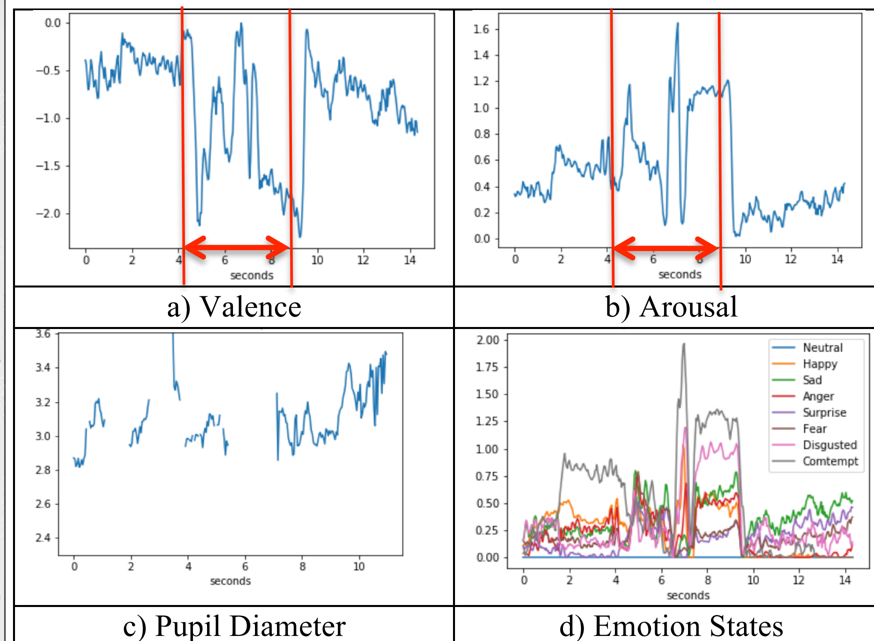
c) Pupil Diameter d) Emotion States

The spike in Valence, Arousal, pupil diameter and fear and disgust (emotion states) corresponds to a self-reported recognition that the situation was hopeless.

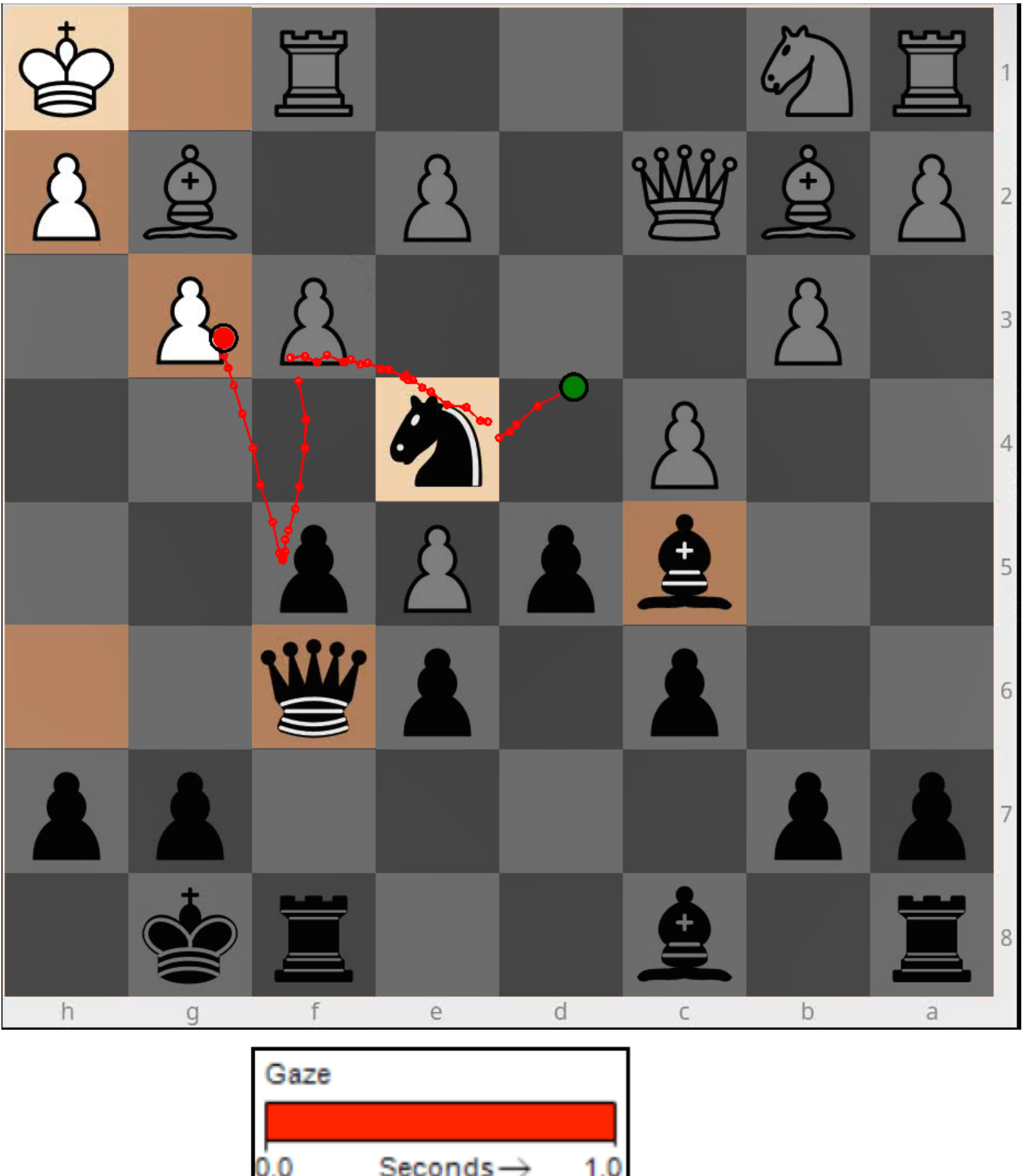
Example: Task 4 (mate in 3)

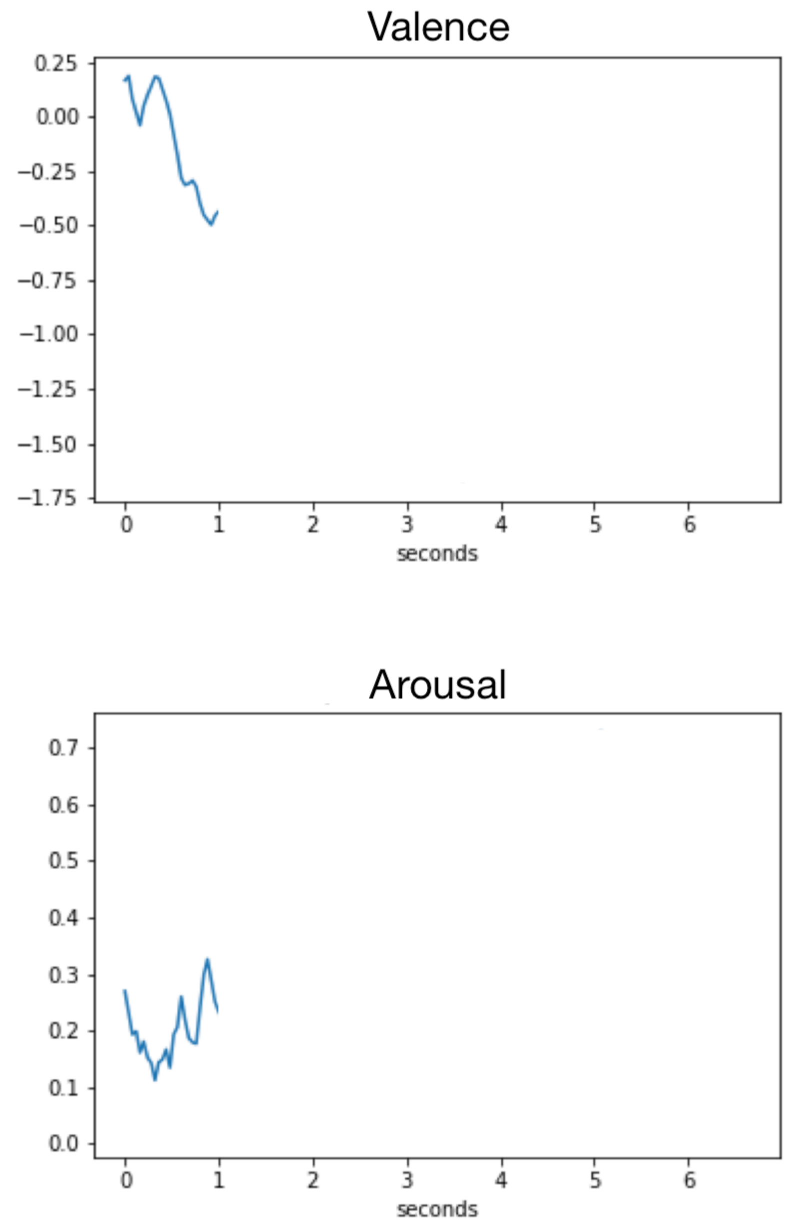


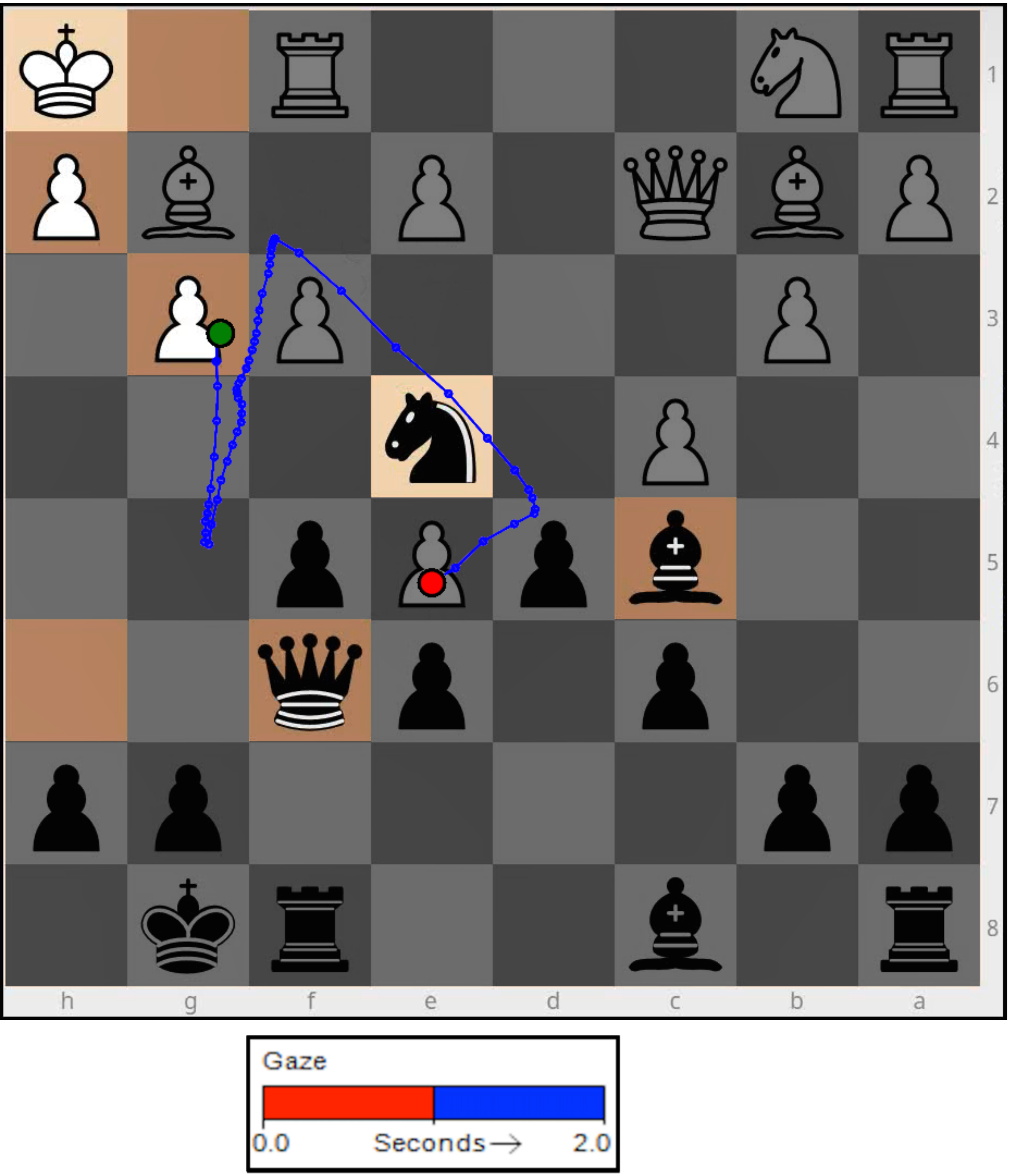
Subject S12 (Expert), Task 4 (mate in 3)



Ok. I see that there is a mate in 3 moves here. It is a kind of pattern because again the king is not able to move at all. There are 3 pieces here, Queen F6, Knight E4 and Bishop at C5."


1
2
3
4
5
6
7
8
h
g
f
e
d
c
b
a
Gaze
0.0
Seconds →
1.0


Valence
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.25
−1.50
−1.75
0
1
2
3
4
5
6
seconds
Arousal
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0
1
2
3
4
5
6
seconds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Gaze
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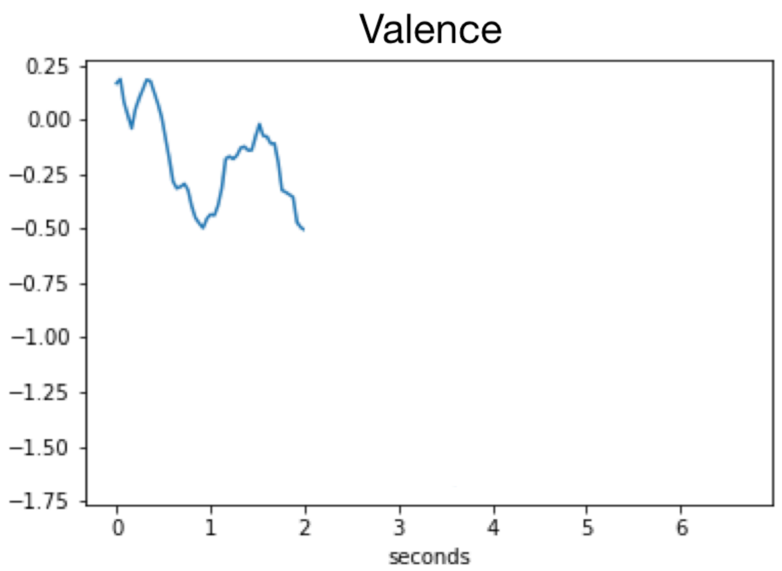
Seconds→
2.0


Valence
0.25
0.00
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−1.00
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3
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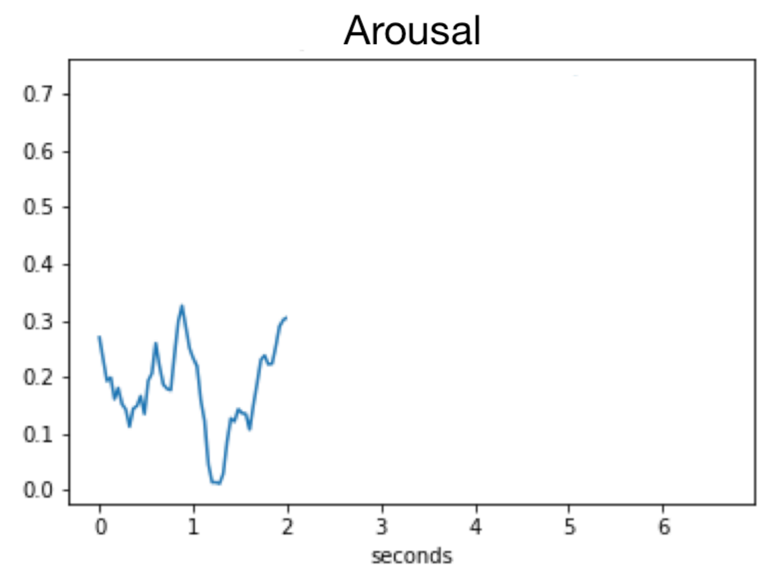
5
6
seconds


Arousal
0.7
0.6
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0.4
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0.0
0
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2
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4
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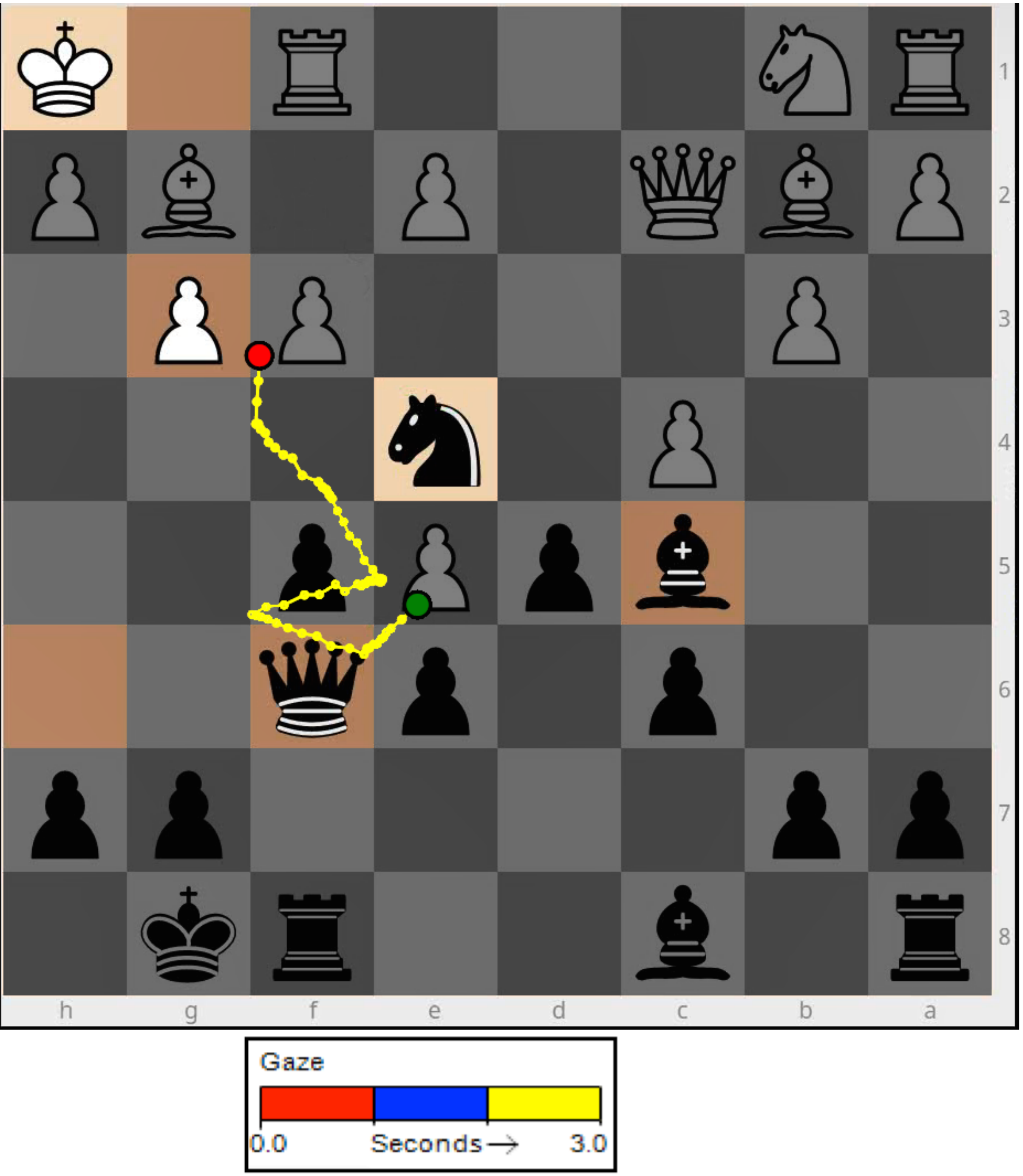
6
seconds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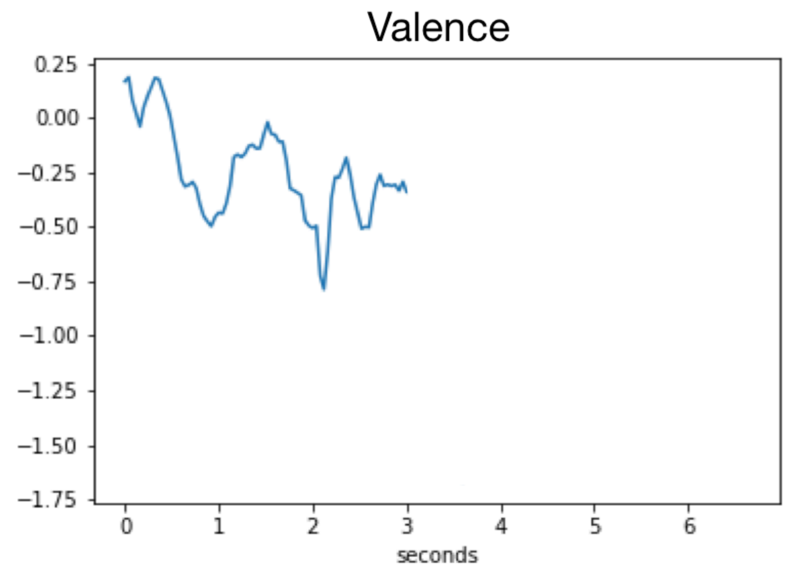
b
a
Gaze
0.0
Seconds →
3.0


Valence
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0.00
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0
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2
3
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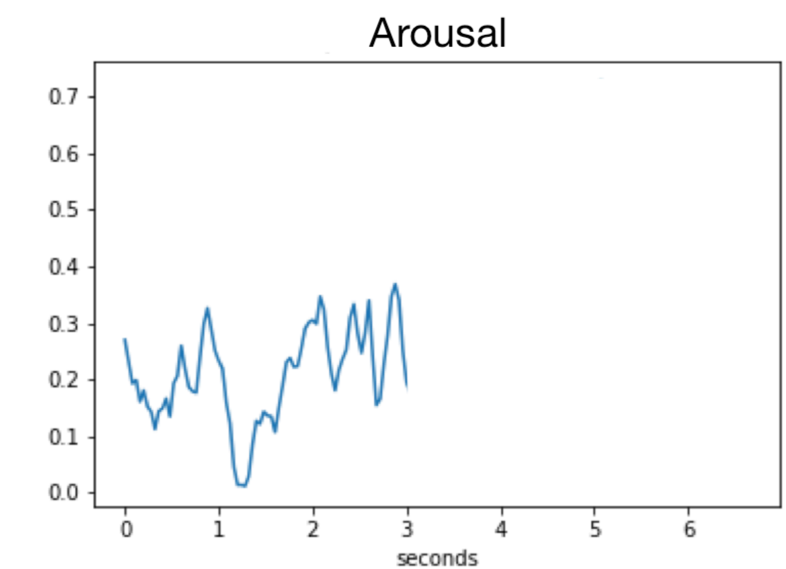
6
seconds


Arousal
0.7
0.6
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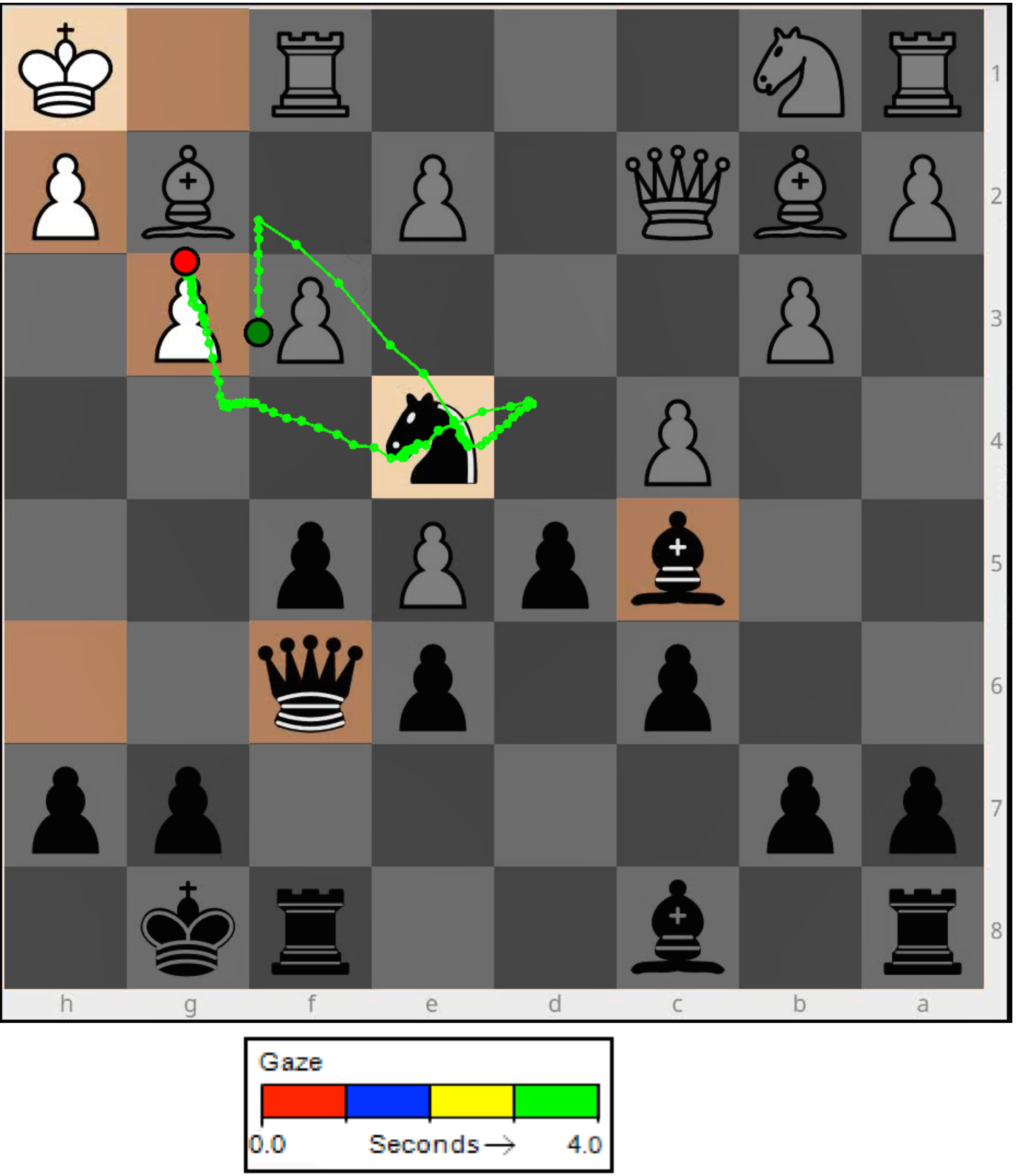
seconds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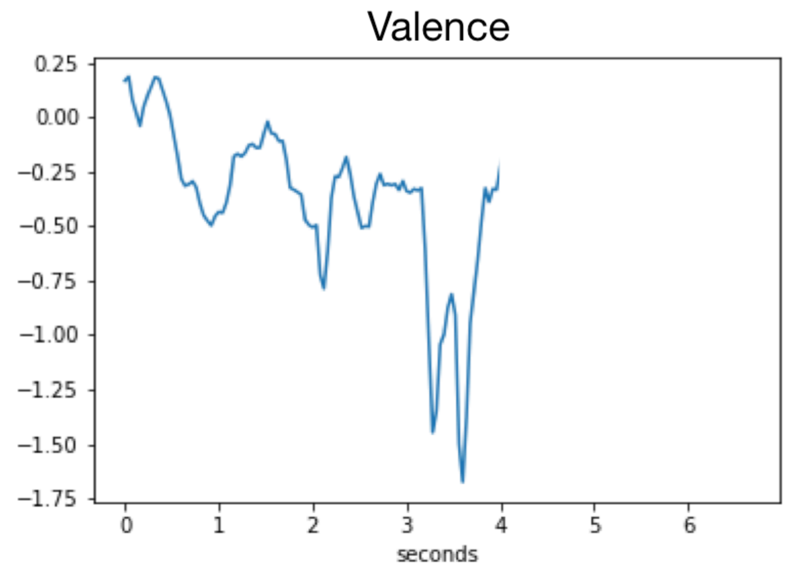
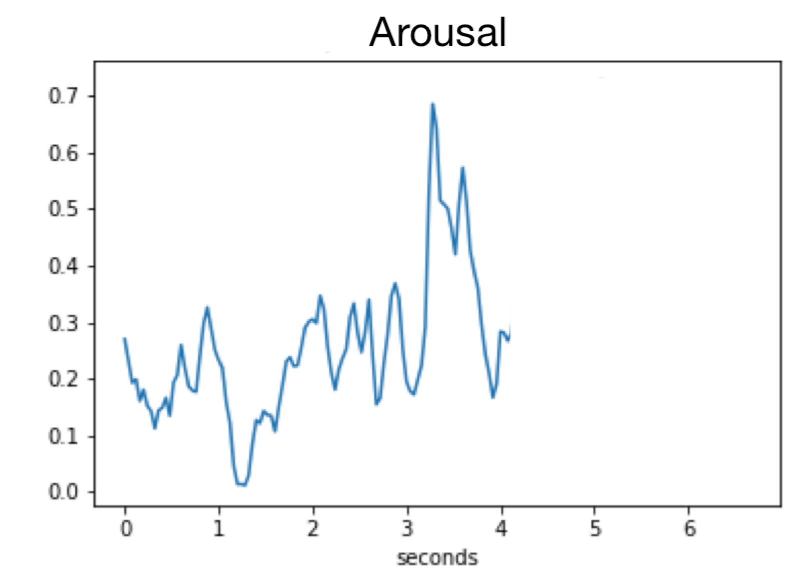
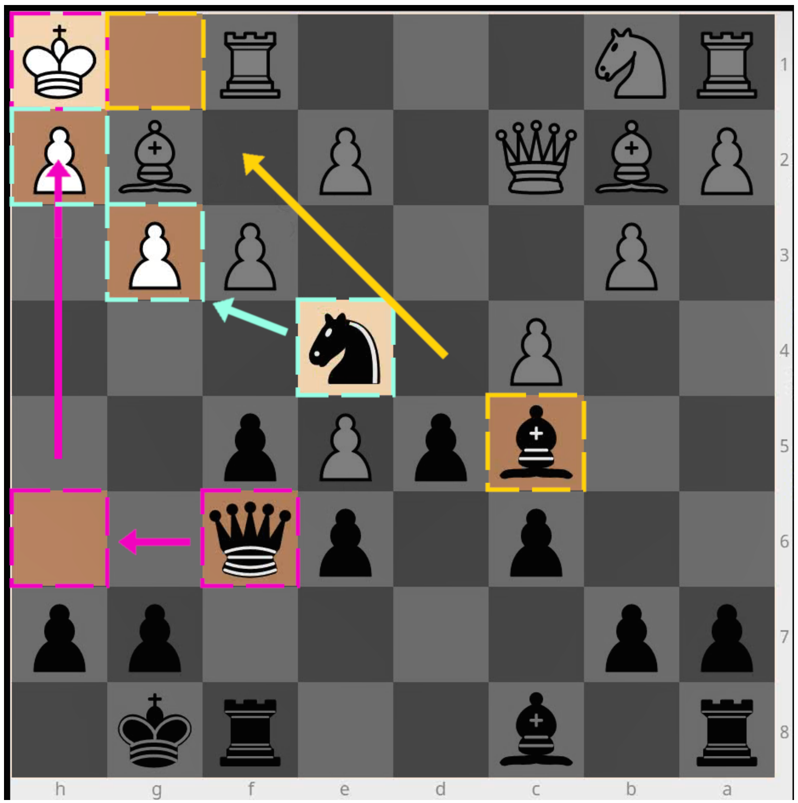
h g f e d c b a
Gaze
0.0
Seconds →
4.0


Valence
0.25
0.00
−0.25
−0.50
−0.75
−1.00
−1.25
−1.50
−1.75
0 1 2 3 4 5 6
seconds


Arousal
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0 1 2 3 4 5 6
seconds

Retroactive Task Explanation by S12



S12 Task Explanation:

“Ok. I see that there is a mate in 3 moves here.

It is a kind of pattern because again the king is not able to move at all.

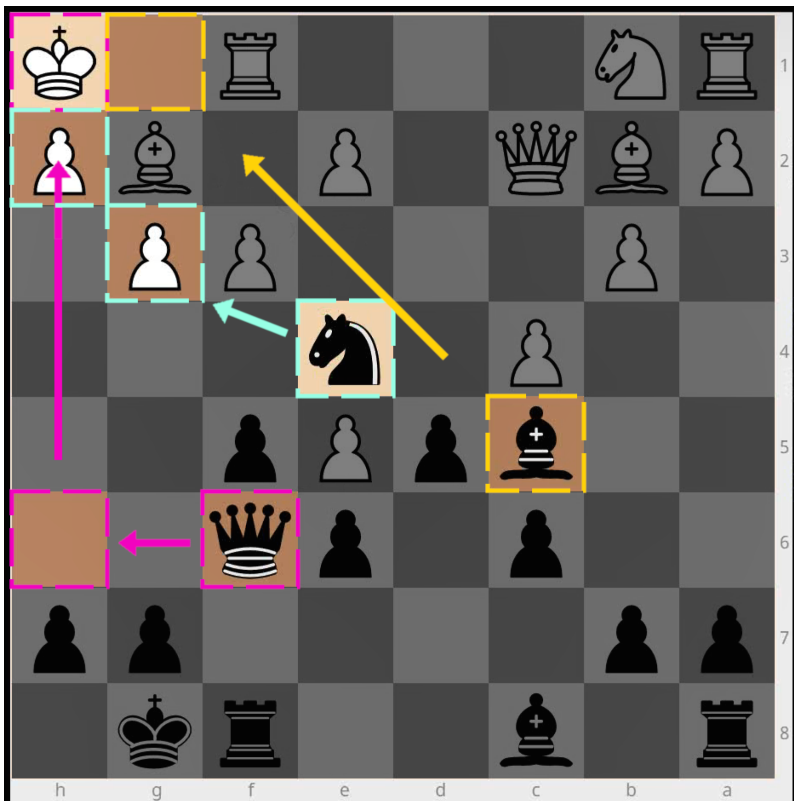
There are 3 pieces here, Queen F6, Knight E4 and Bishop at C5. So the bishop already controls the only available square of the white king, so there are two pieces.

So first check with the knight then the queen. ”

(Knight takes Pawn, check, Pawn H2 at takes Pawn , Queen to H6 Check mate).

WORK IN PROGRESS

Grand Challenge: Automatically Generate Narratives for Player Comprehension.



Chess Concepts:

- C1. Bishop Blocks King
- C2: Knight threatens Pawn
- C3: Pawn takes Knight
- C4: Queen Checks King

Subjects Plan:

S1: Knight (E4) Takes Pawn (G3)

- S2: Pawn (H2) takes Knight (G3)
- S3: Queen to H6 Check-mate

Potential Applications

- Collaborative Intelligent Systems
  - Intelligent Auto-pilot and Drivers Assistant for aircraft, automobiles, trucks, buses, heavy equipment
  - Collaborative robots for manufacturing and service industry
- Training and Education
  - Student Aware intelligent training Pulpit
  - Training for driving vehicles and heavy equipment.
- Socially aware Service Robots
- Human aware personal mobile devices
- Ambient Intelligence
  - Smart Home, furniture, desk, kitchen etc.

SATT Linksium Project MAT / Sym2B

SYM2B Truck Simulator with 6 axis Motion chair

Sym2B estimates for market for driver training simulators:

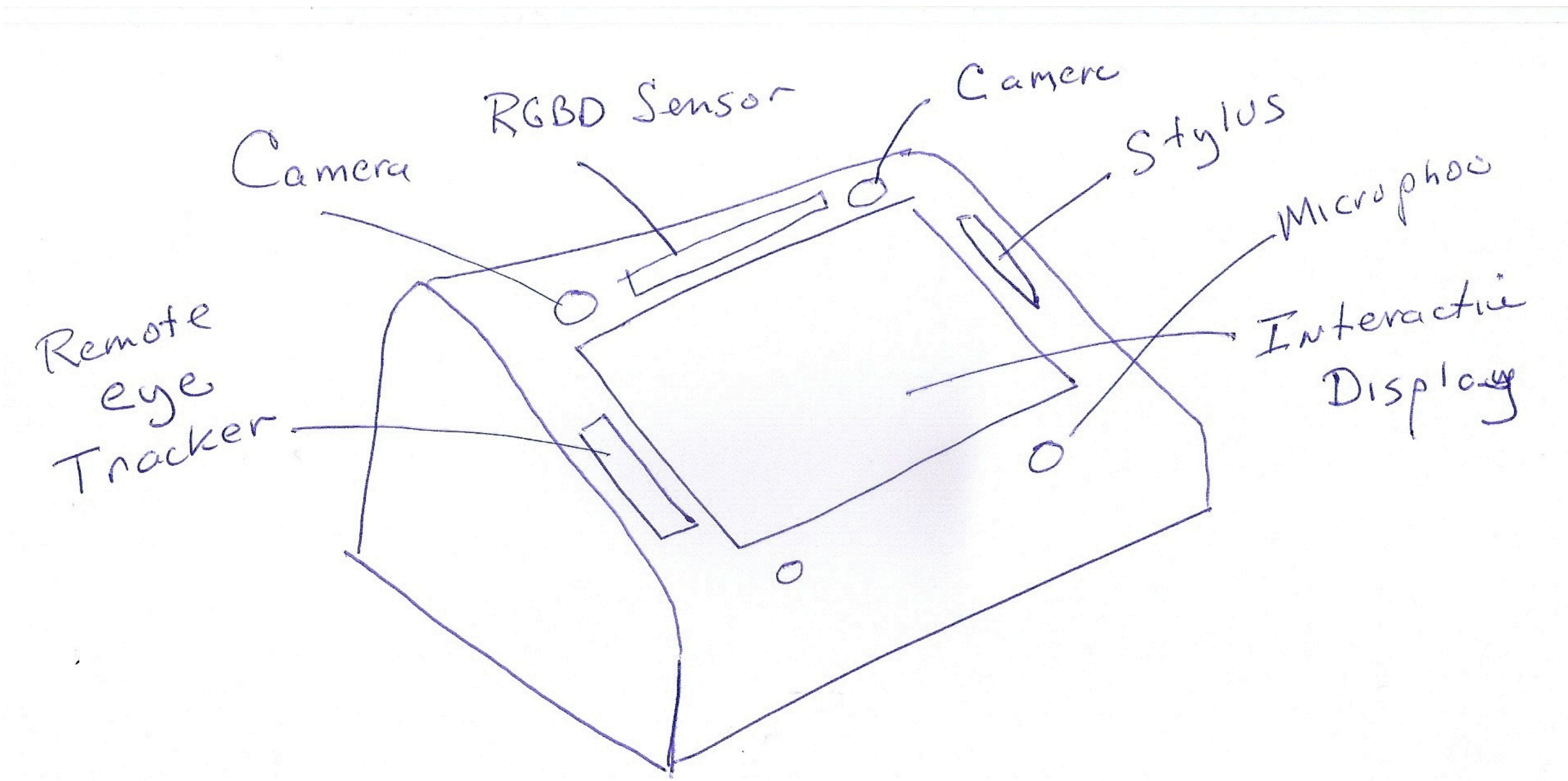
- 400 Truck Simulators
- 150 bus Simulators
- 100 cars Simulators

Training simulator augmented with remote eye-tracking, face expression analysis, pupil dilation and body gesture models.

Project start 1 Sept 2019

Student Aware Training Pulpit

Collaboration with Philippe Dessus and Fanny Gimbert (LaRAC)



Limitations

(Work in Progress!)

- Proposed models explain comprehension and predict behavior. They do not prescribe implementation.
- Chess is much simpler than the real world! We can potentially constrain possible interpretations of eye-scan.
- Very preliminary investigation (TRL 2!) Models have not yet been evaluated. Value will be their usefulness for prediction and explanation.

Open Challenges

1. How can enumerate the set of possible concepts (chunks) for a problem space?
2. What is the best way to define the "activation" field(weights and span) for fixation on a visual phenomena?
3. Can we detect evidence for awareness from other sensor modalities?
4. Can we detect evidence for awareness from emotions?

CEEGE Publications (Inria)

Journal Papers

1. T. Guntz, R. Balzarini, D. Vaufreydaz, and J.L. Crowley, "Multimodal Observation and Classification of People Engaged in Problem Solving: Application to Chess Players". *Multimodal Technologies and Interaction*, Vol. 2 No. 2, p11, 2018.

Conference and Workshop.

1. T. Guntz, R. Balzarini, D. Vaufreydaz et J. L. Crowley, Multimodal Observation and Interpretation of Subjects Engaged in Problem Solving, at the Workshop on Behavior, Emotion and Representation: Building Blocks of Interaction, Bielefeld, 2017.
2. P. Dessus, L.-H. Aubineau, D. Vaufreydaz, J. L. Crowley. *A Framework for a Multimodal Analysis of Teaching Centered on Shared Attention and Knowledge Access*, in "Grenoble Workshop on Models and Analysis of Eye Movements", Grenoble, France, June 2018,
3. T. Guntz, J.L. Crowley, D. Vaufreydaz, R. Balzarini, P. Dessus , The role of emotion in problem solving: first results from observing chess, Workshop on Modeling Cognitive Processes from Multimodal Data, at International Conference on Multimodal Interaction, ICMI 2018, Oct 2018.
4. J. L. Crowley Put That There: 20 Years of Research on Multimodal Interaction, 2018 International Conference on Multimodal Interaction, ICMI 2018, Boulder Co. Oct 2018.
5. J. Le Louedec, T. Guntz, J. L. Crowley, D. Vaufreydaz, Deep learning investigation for chess player attention prediction using eye-tracking and game data, ETRA, ACM Symposium on Eye Tracking Research ans Applications, Denver, Colorado, June 2019

Academic Reports (Inria)

Masters Student Project Reports

1. Laura Lassance de Oliveira Morais, Multimodal analysis of effectiveness of video lecture design, Master of Science in Informatics at Grenoble, June 2018
2. Justin Le Loudec, Deep learning investigation for chess player attention prediction using eye-tracking and game data, Master of Science in Informatics at Grenoble, Sept 2018.

Habilitation a Diriger le Recherche

1. Dominique Vaufreydaz, Perception Multi-modale et Interaction Sociable, Memoire, Habilitation a Diriger les Recherches, Univ Grenoble Alpes, 24 juillet, 2018

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ANR/DFG - CEEGE
Chess Expertise from Eye Gaze and Emotion

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