

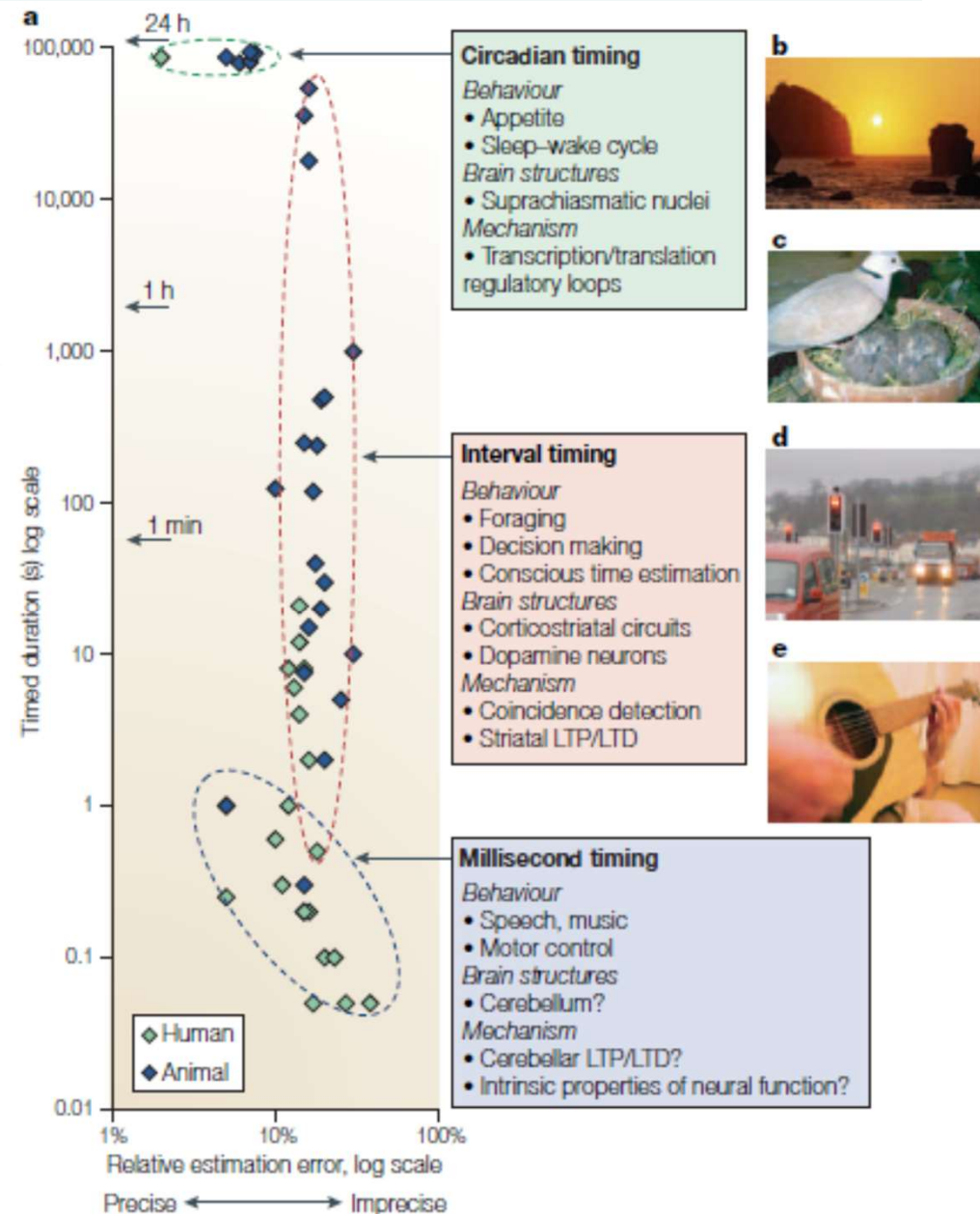


Basi neurocognitive del senso del tempo

Timing across different timing scales

Una rassegna, di dati provenienti da vari studi che indicano la precisione dell'uomo e di altri animali nell'eseguire compiti di stima del tempo.

- b - I ritmi circadiani sono i più riconoscibili in natura (c), ma anche le durate nell'ordine dei millisecondi guidano il comportamento animale.
- (d) la percezione del tempo è implicata nei processi decisionali
- (e) il timing nell'ordine dei millisecondi risulta centrale per la riproduzione della musica



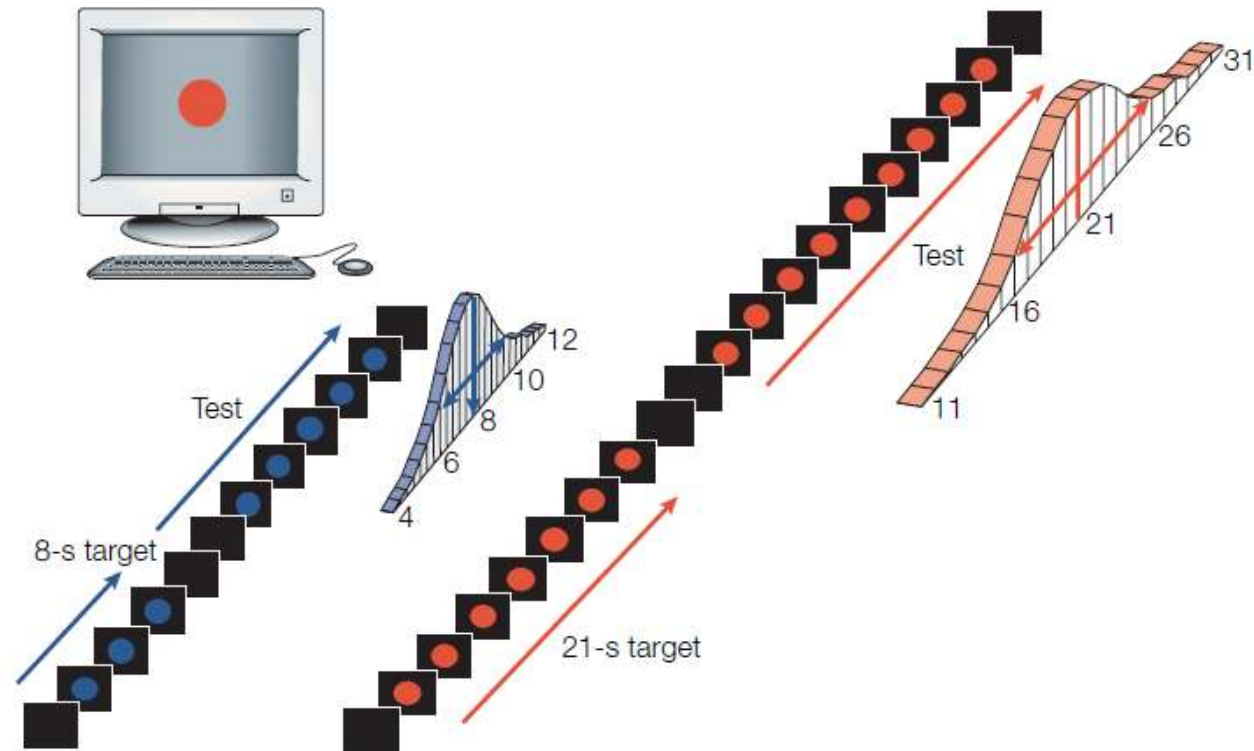
Proprietà empiriche nello studio della stima del tempo

- **The scalar property**
- **The Vierordt's law**
- **The modality effect**
- **Filled-duration illusion**
- **Time-order error**

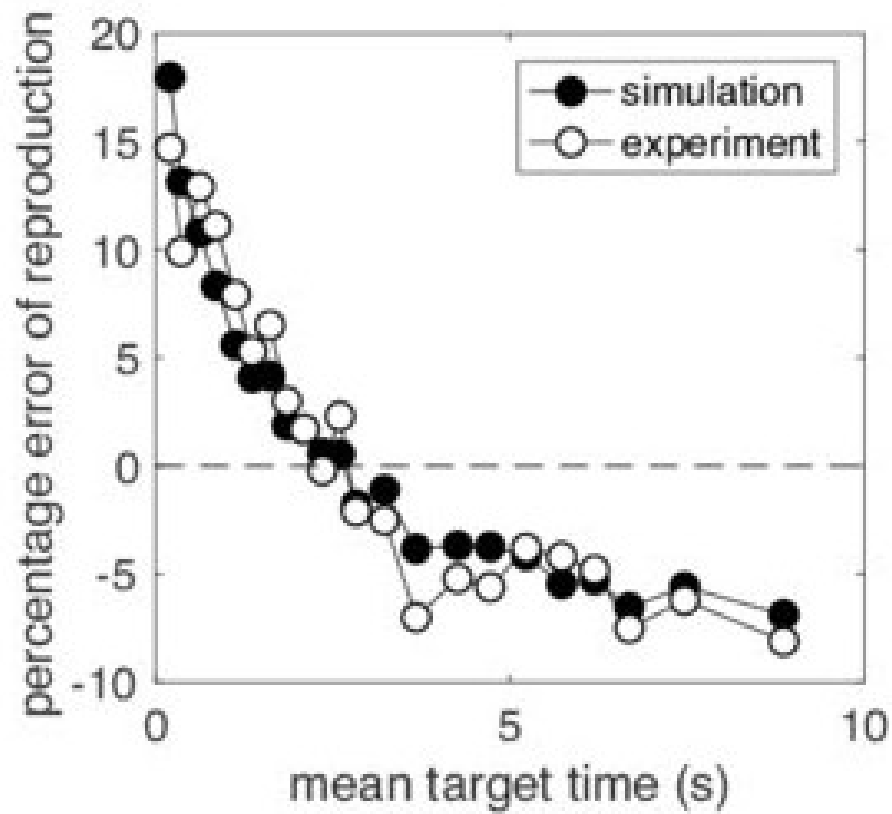
The scalar property of temporal estimation

La **risposta** del partecipante segue una distribuzione normale attorno la durata dello stimolo di riferimento.

L'ampiezza della distribuzione di questa risposta risulta proporzionata alla durata dello stimolo.



The Vierordt's **law**



The modality effect

Il tempo è percepito diversamente a seconda della modalità:

UDITIVO > VISIVO

Gli stimoli uditivi sembrano più lunghi.



Filled-duration illusion

Intervalli “riempiti” (con stimoli continui)

→ *percepiti più lunghi* di intervalli vuoti

👉 classico e intuitivo per il pubblico

INTERVALLO RIEMPITO



INTERVALLO DI 10 SECONDI

PERCEZIONE
PIÙ LUNGA

✓ RIEMPITO

percepito
più lungo di



INTERVALLO VUOTO



INTERVALLO DI 10 SECONDI

INTERVALLO DI 10 SECONDI

PERCEZIONE
PIÙ BREVE

✓ VUOTO

Time-order error

La stima dipende dall'ordine di presentazione

Il primo intervallo influenza il secondo

👉 importante per paradigmi comparativi



Un classico modello esplicativo: *The pacemaker-accumulator model*

1. Pacemaker = il "metronomo" del cervello

- Produce impulsi regolari (come tic di un orologio)
- Più impulsi = più tempo percepito

2. Switch / gate = l'interruttore

- Si **apre** quando inizia lo stimolo
- Si **chiude** quando finisce
- 👉 decide quando iniziare e fermare il conteggio

3. Accumulator = il contatore

- Conta quanti impulsi arrivano dal pacemaker
- 👉 più impulsi accumulati = durata percepita più lunga

4. Working memory = memoria temporanea

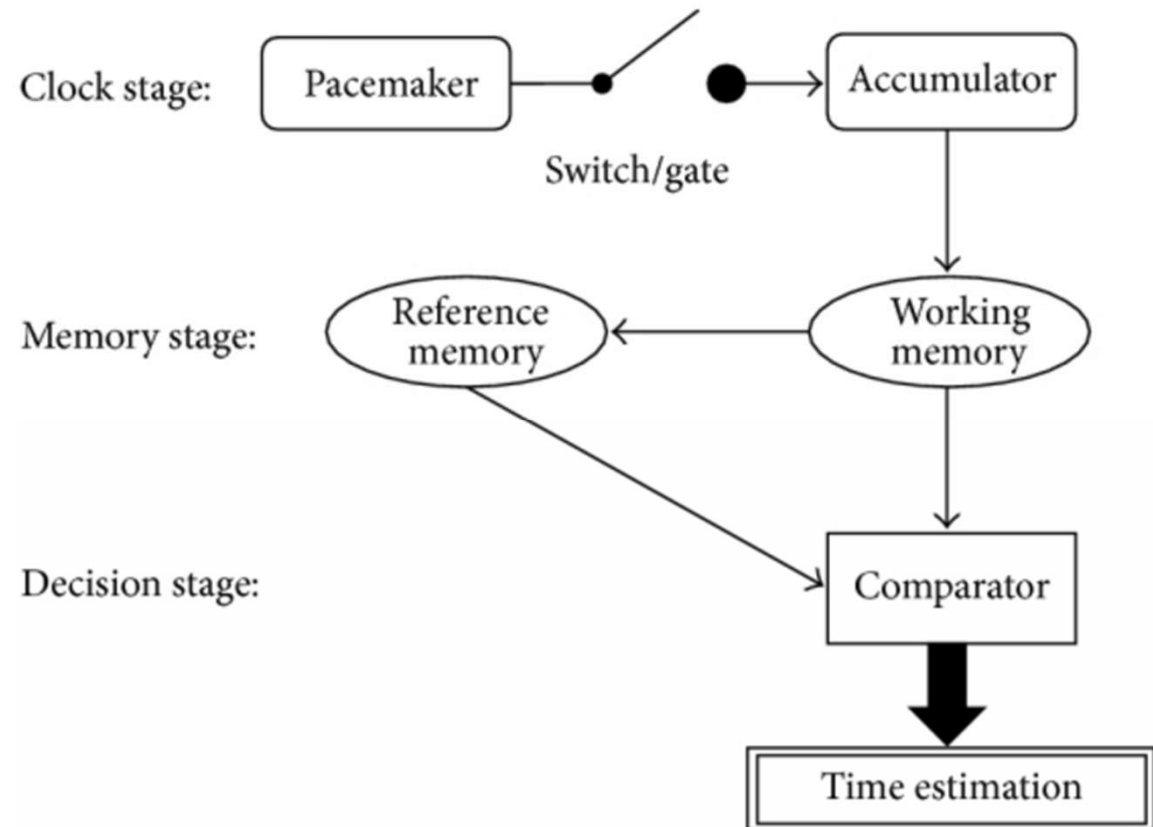
- Tiene il numero appena contato
- 👉 "quanto è durato questo intervallo?"

5. Reference memory = memoria di confronto

- Contiene durate già apprese (es. "quanto dura 1 secondo")

6. Comparator = il giudice

- Confronta: tempo appena stimato con tempo memorizzato
- 👉 decide se è "più lungo", "più corto", ecc.



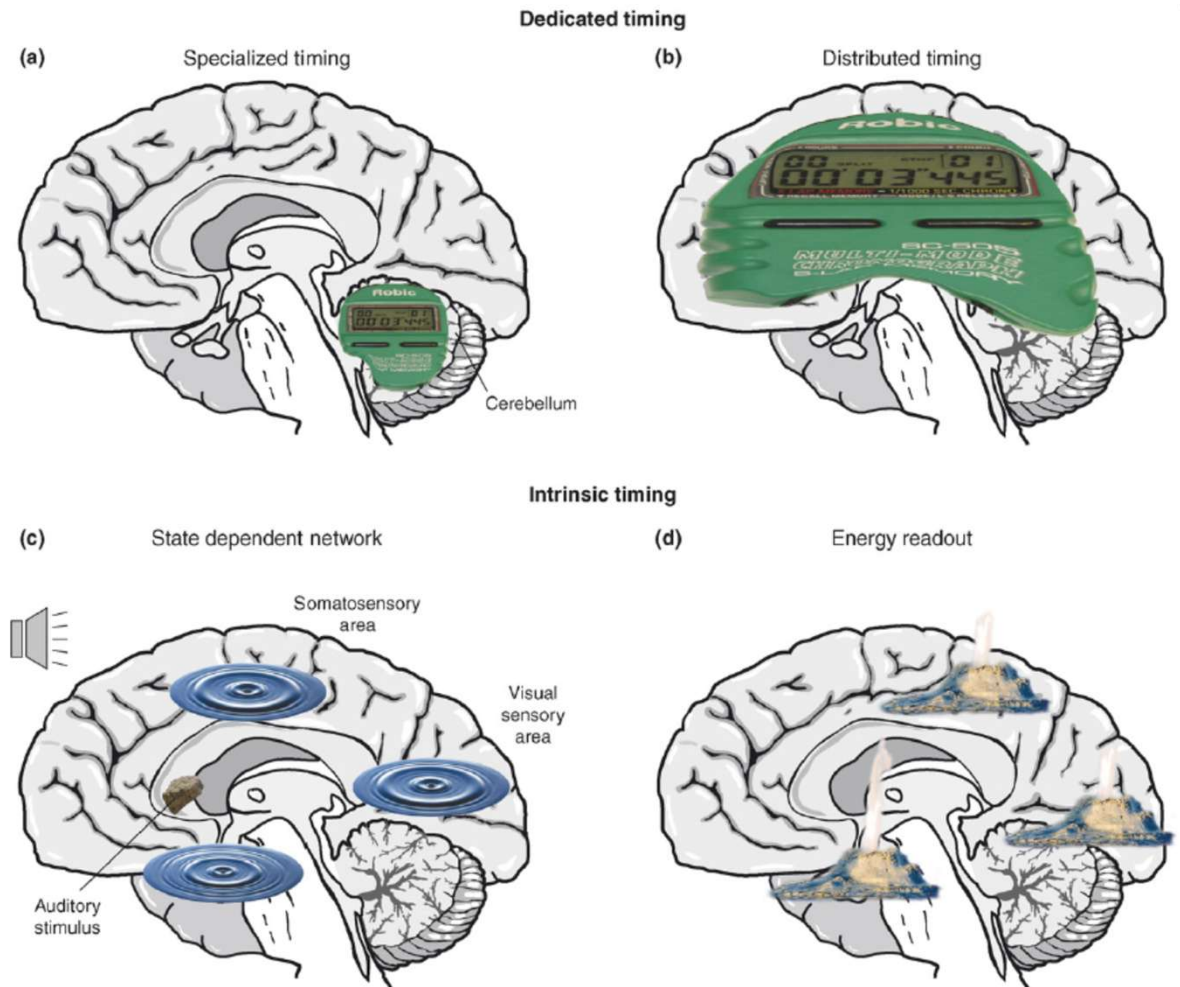
Modelli di rappresentazione del tempo

(a) Una struttura neurale potrebbe essere specializzata per rappresentare il tempo.

b) Un sistema dedicato potrebbe coinvolgere una rete distribuita di regioni neurali.

c) In questo modello i **patterns temporali** sono rappresentati come **patterns spaziali**

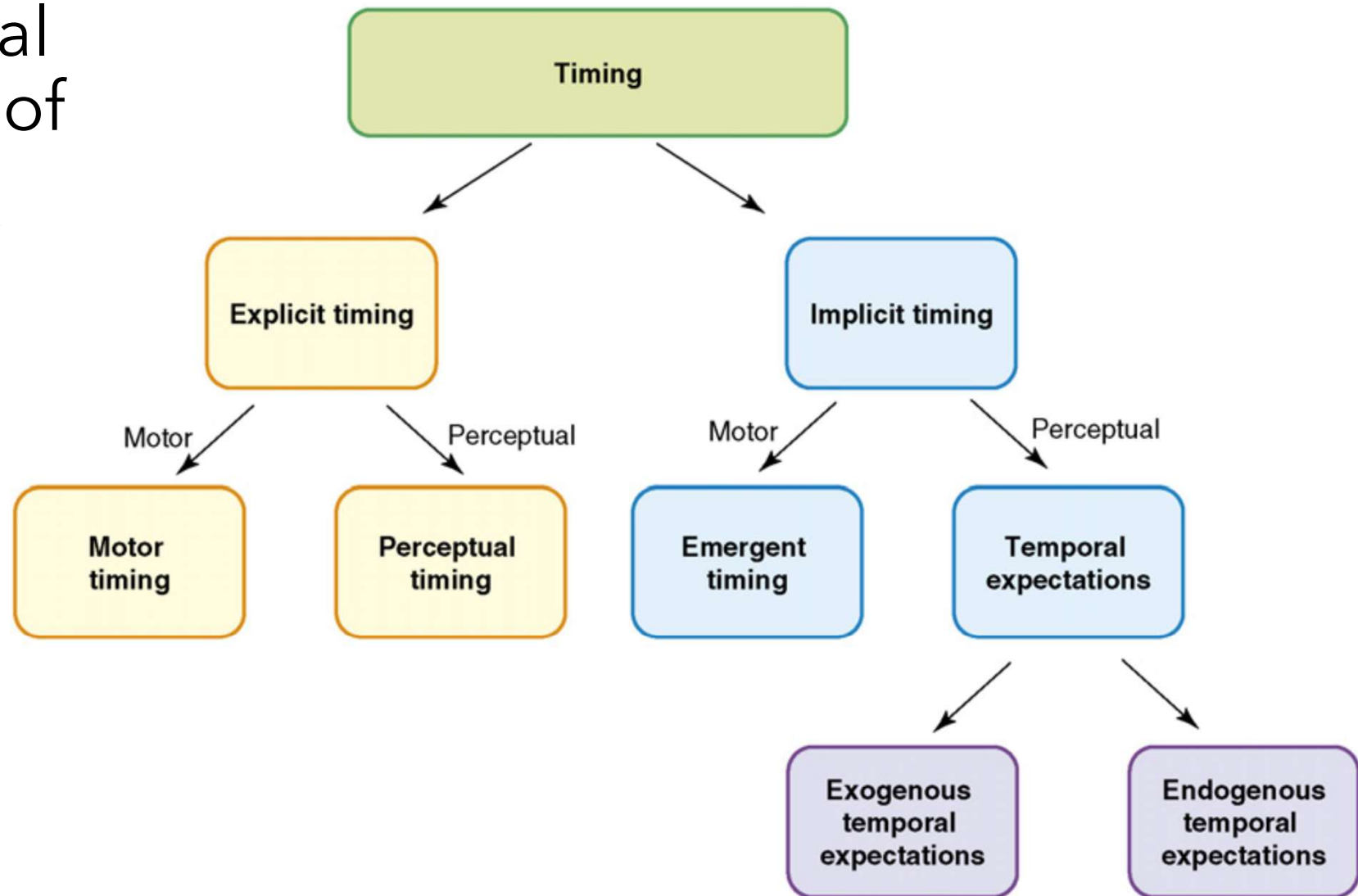
d) Nel modello «*energy readout*», il tempo trascorso corrisponde alla quantità di attività neurale (congruenza).



Terminologie ricorrenti nella letteratura sulla stima del tempo

- Una distinzione generale e' quella tra **Prospective timing** & **Retrospective timing**
- Una distinzione ulteriore e' quella tra **timing motorio e timing sensoriale** (La stima del tempo puo' coinvolgere tutti i sensi)
- Inoltre occorre distinguere tra **timing automatico** (subsecond) e **timing cognitivamente controllato** (suprasecond + attention and WM).

A functional taxonomy of timing





Alcuni paradigmi per lo studio della stima del tempo

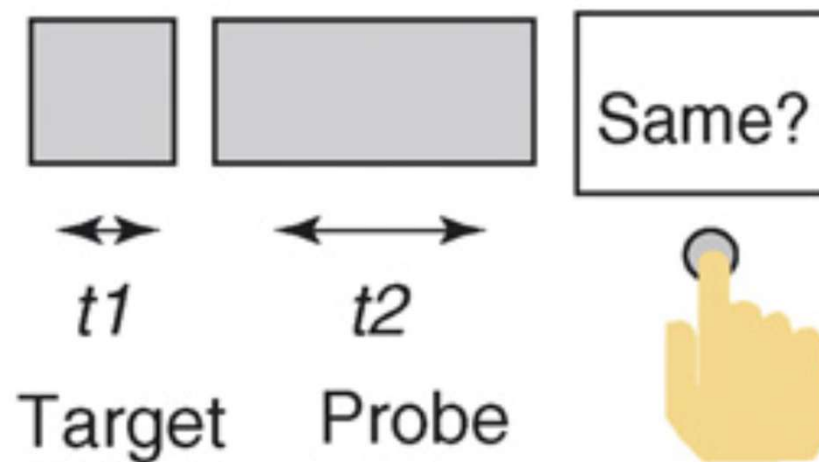
Explicit timing: In quanti modi e' possibile stimare il tempo?

Diversi tipi di compiti:

- Time discrimination
- Time reproduction
- Finger tapping
- Time production
- Time bisection
- Temporal expectation

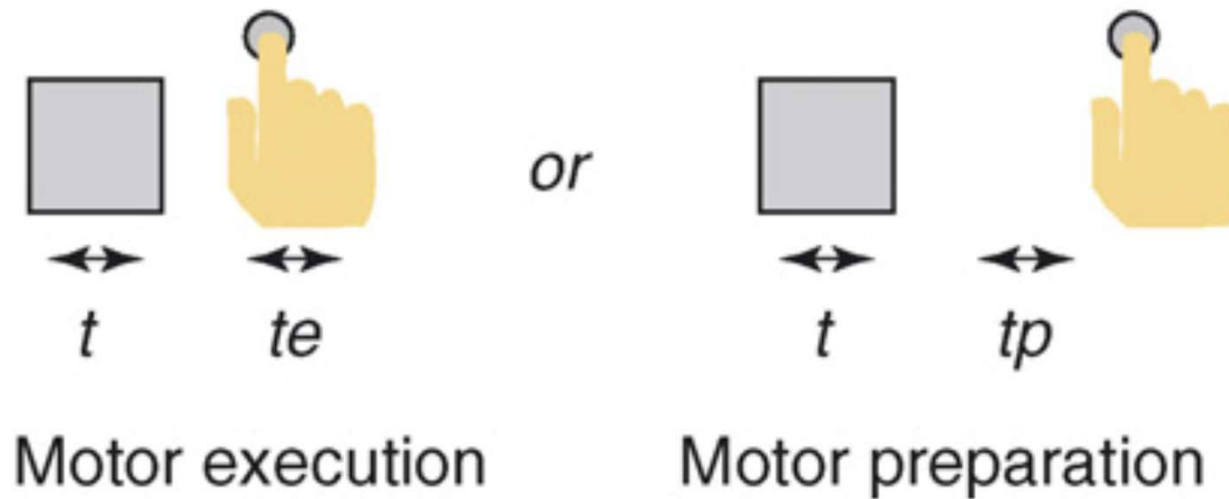
Temporal discrimination task

(a) Temporal discrimination



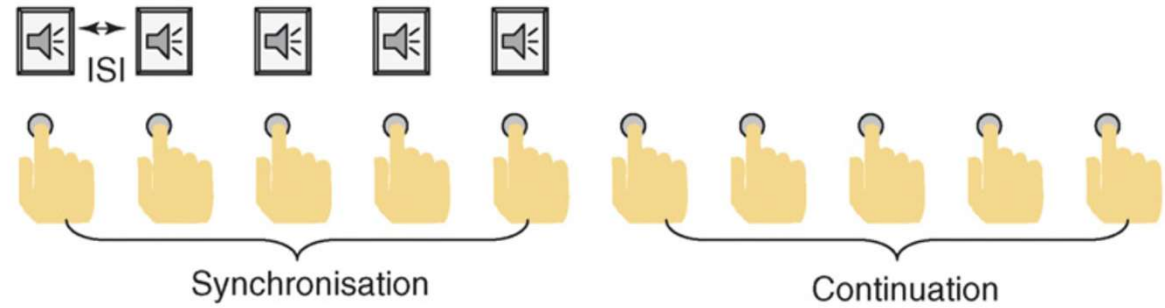
Time reproduction task

(b) Temporal reproduction



Finger tapping

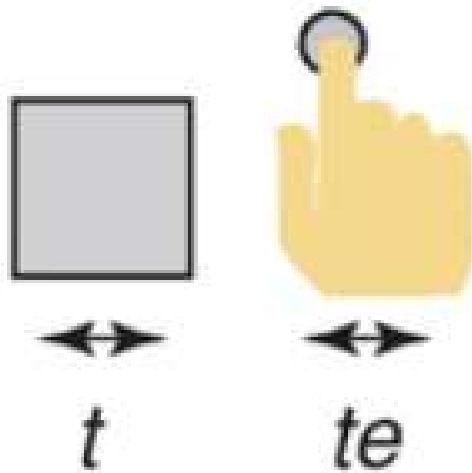
(c) Paced finger tapping



Time production

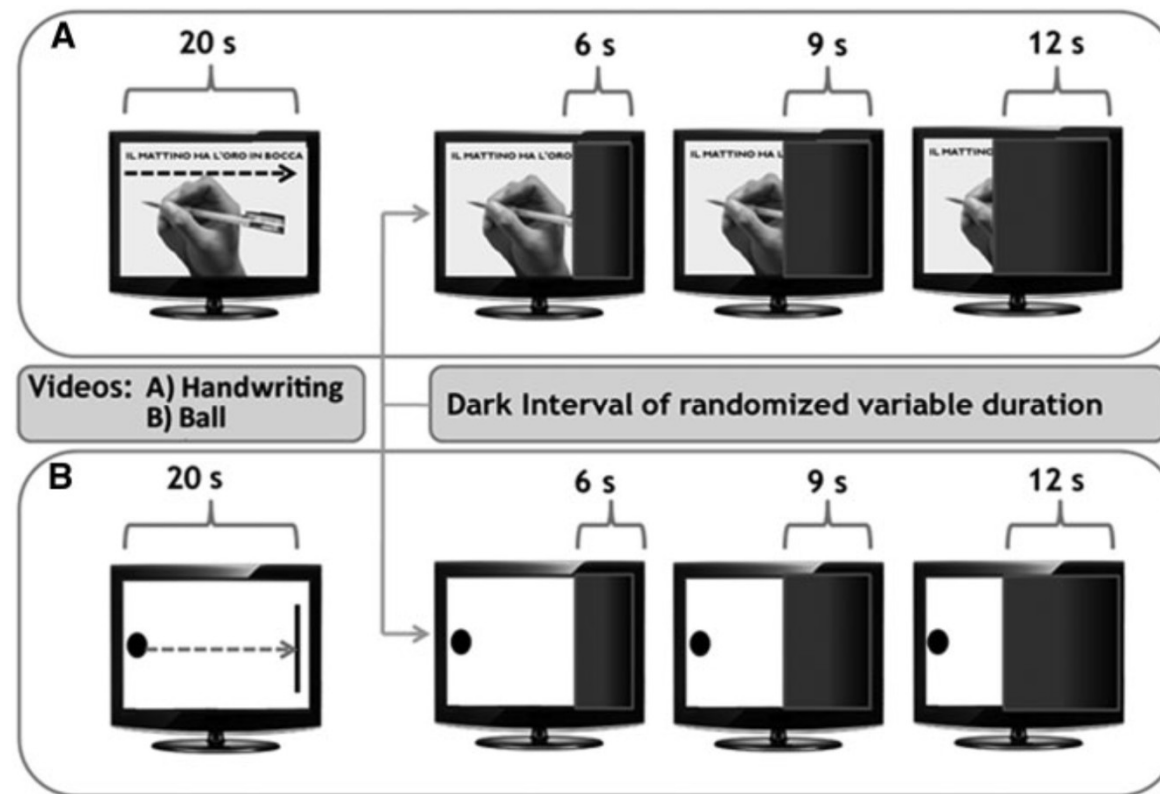


Time bisection



Motor execution

(Explicit) Temporal prediction task

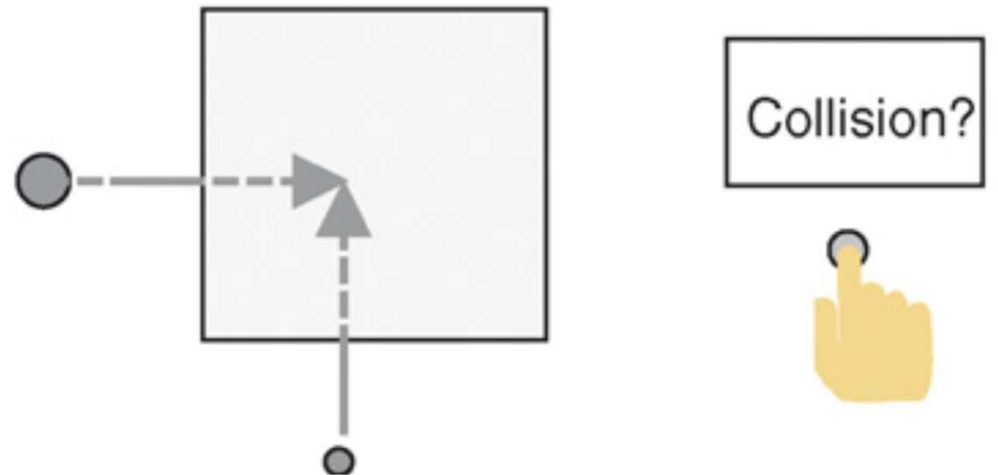


Implicit timing: In quanti modi e' possibile stimare il tempo?

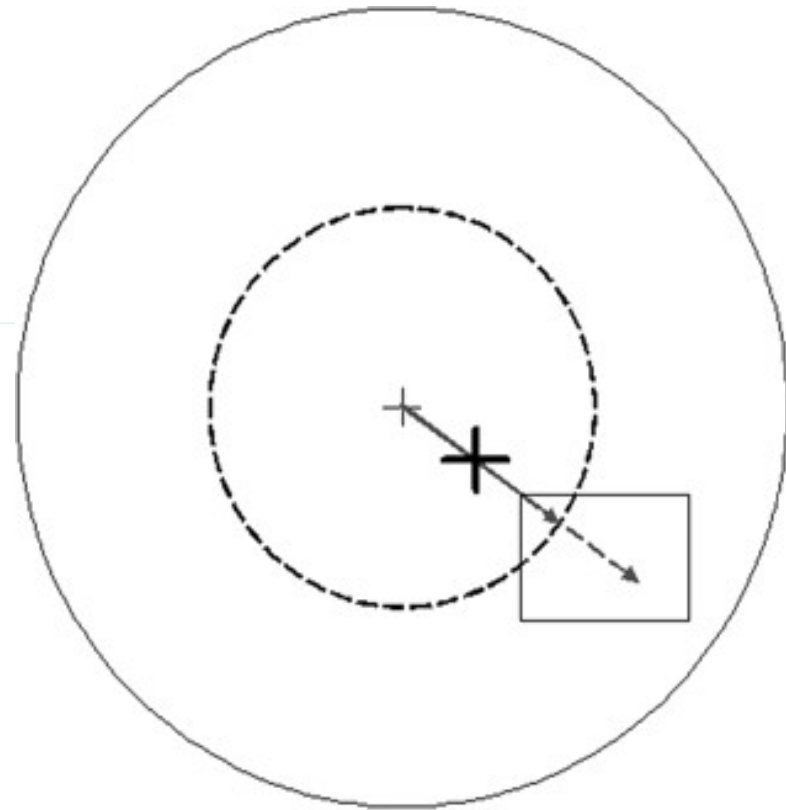
- Temporal expectation task

(implicit) Temporal expectation task

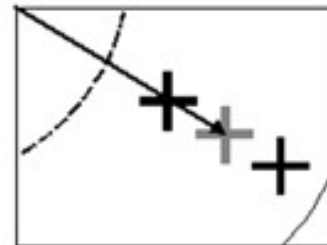
(a) Spatio-temporal trajectories



Temporal expectation task



The velocity judgment task



Questionari per la stima del tempo

The Zimbardo Time Perspective Inventory

5 sottoscale:

Past-Positive, che riflette un atteggiamento caloroso, sentimentale, positivo verso il passato (**punteggio ideale alto, intorno a 4.5**);

Passato-negativo, che riflette un aspetto generalmente negativo del passato (**punteggio ideale basso, intorno a 2**)

Presente edonistico, che riflette un'attitudine al piacere e rischio nei confronti del tempo e vita (**punteggio ideale intorno a 4**)

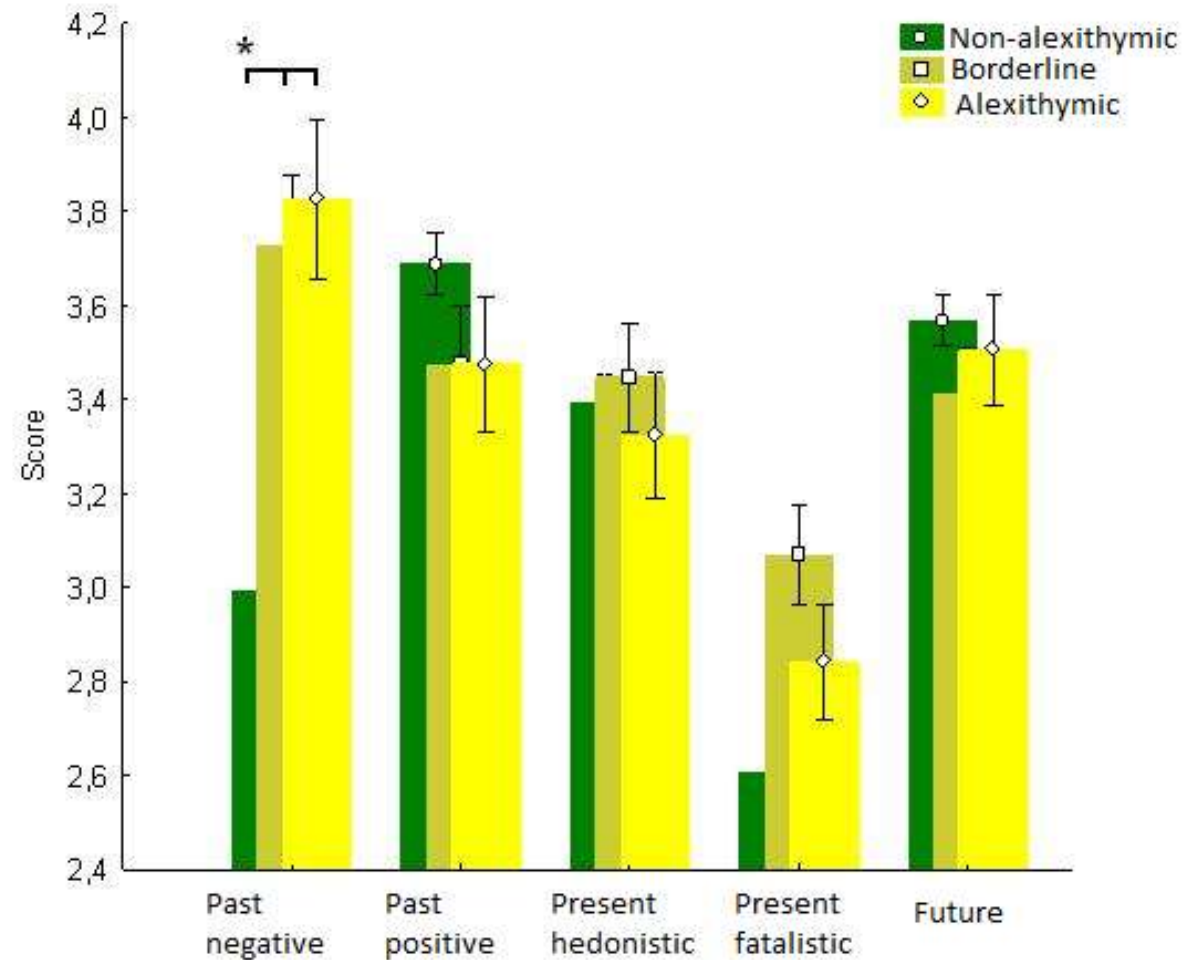
Presente-fatalista, che misura un atteggiamento fatalista, ovvero percepirsi indifesi e senza speranza verso il futuro e la vita; (**punteggio ideale intorno a 1.5**)

Futuro, misura un generale orientamento che comprende la pianificazione e il raggiungimento di obiettivi futuri, anche a scapito del godimento attuale, della **gratificazione ritardata** (**punteggio ideale intorno a 4**)

	Molto Falso		Neutro	Molto Vero	
	1	2	3	4	5
1. Credo che festeggiare con gli amici sia uno dei piaceri importanti della vita.					
2. Le immagini, i suoni, gli odori familiari dell'infanzia richiamano una quantità di ricordi meravigliosi.					
3. Il destino conta molto nella mia vita.					
4. Spesso penso alle cose che avrei dovuto agire in modo diverso nella mia vita.					
5. Le mie decisioni sono molto influenzate dalle persone e dalle cose intorno a me.					
6. Io penso che la giornata di una persona dovrebbe essere programmata in anticipo ogni mattina.					
7. Mi dà piacere pensare al mio passato.					
8. Io faccio le cose impulsivamente.					
9. Non mi preoccupa se le cose non sono fatte in tempo.					
10. Quando io voglio raggiungere qualcosa, io stabilisco gli obiettivi e considero i mezzi specifici per raggiungerli.					
11. Complessivamente ci sono più cose belle che brutte da ricordare nel mio passato.					
12. Io spesso perdo la nozione del tempo, quando ascolto la mia musica preferita.					
13. Rispettare le scadenze di domani ed eseguire il lavoro che è necessario completare viene prima del divertimento di stasera.					
14. Dato che quello che sarà sarà, non è così importante ciò che faccio.					
15. Mi piace sentir raccontare storie di : "come erano le cose nei bei vecchi tempi".					
16. Le esperienze dolorose che ho vissuto in passato continuano a tornarmi in mente.					
17. Cerco di vivere giorno dopo giorno pienamente la mia vita.					
18. Mi disturba molto arrivare in ritardo agli appuntamenti.					
19. Per me l'ideale sarebbe vivere ogni giorno come se fosse l'ultimo.					
20. I ricordi felici dei bei tempi nascono spesso nella mia mente.					
21. Rispetto sempre nei tempi stabiliti gli impegni verso i miei amici e le autorità.					
22. Ho avuto la mia parte di maltrattamenti e/o di rifiuti nel passato.					
23. Io prendo decisioni su due piedi.					
24. Vivo la mia giornata come viene piuttosto che programmarla.					
25. Il passato ha troppi brutti ricordi a cui io preferisco non pensare.					
26. E' importante rendere eccitante la mia vita.					

Tratti di personalità e stima del tempo: Alexithymia is linked with a negative bias for past and current events in healthy humans

Quali implicazioni??



Barchetta et al., 2021.

Come analizzare la performance temporale?

- Accuracy

- Variability

$$C_v = \frac{S_{n-1}}{\bar{x}}$$

Coefficiente di Variazione

$$S_{n-1} = \sqrt{\frac{1}{n-1} \cdot \sum_{i=1}^n (x_i - \bar{x})^2}$$

Deviazione Standard

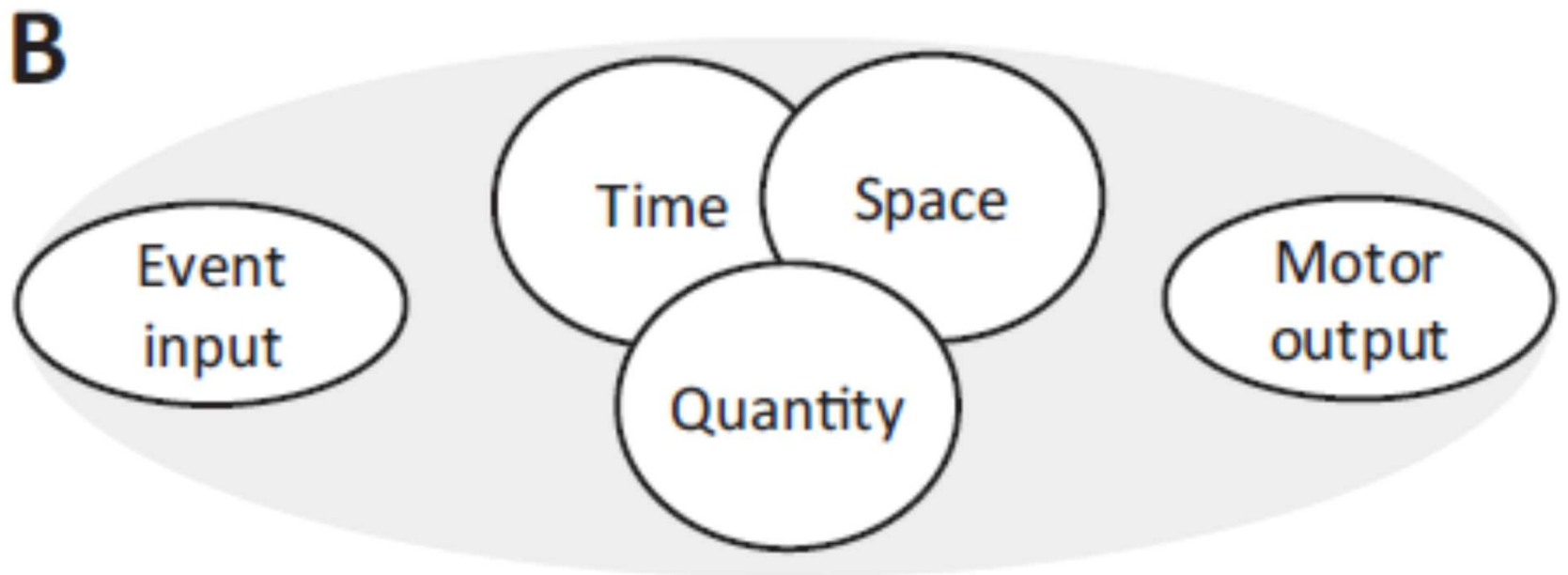
$$\bar{x} = \frac{1}{n} \sum_{i=1}^n x_i$$

Valor medio

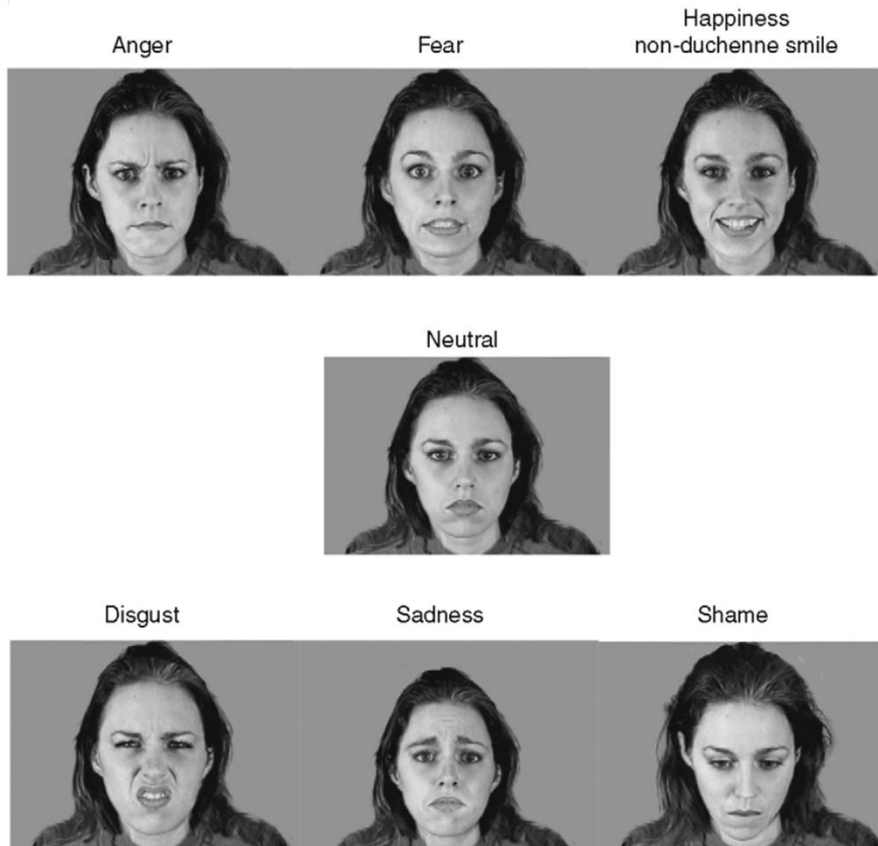
Variabili che influenzano il senso del tempo

- Nontemporal stimulus properties (perception)
- The allocation of processing resources (attention)
- Body states

Subjective duration is affected by nontemporal stimulus properties (magnitude perception)

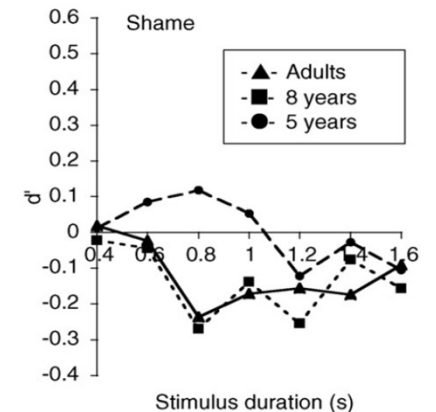
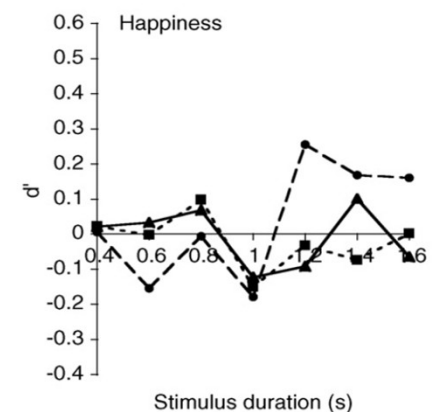
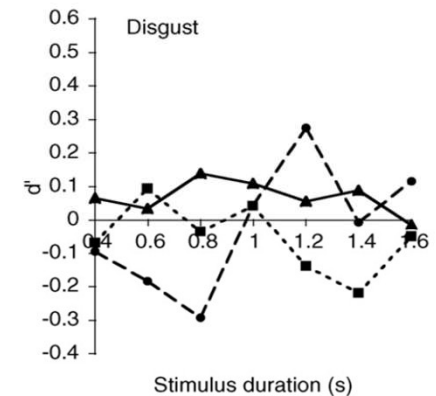
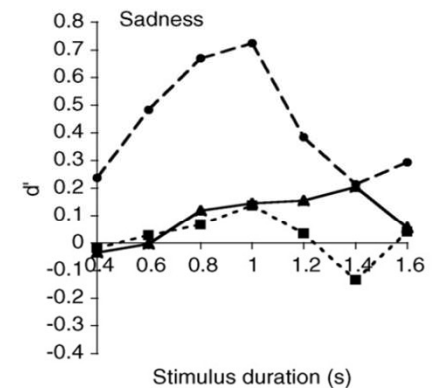
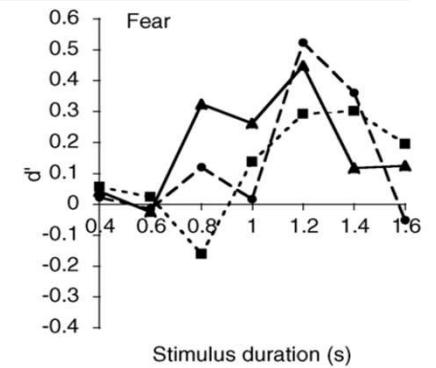
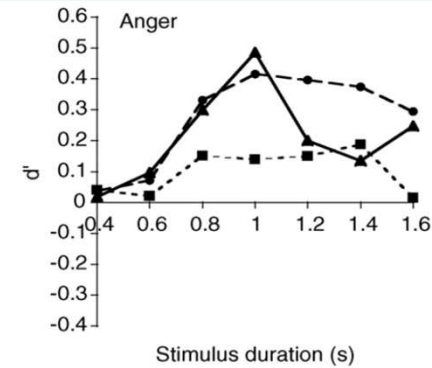


Subjective duration is affected by nontemporal stimulus properties (Emotions)



A d' greater than zero indicates that the emotional expression is **overestimated** compared with the neutral expression

A d' shorter than zero indicates that the emotional expression is **underestimated** compared with the neutral expression.

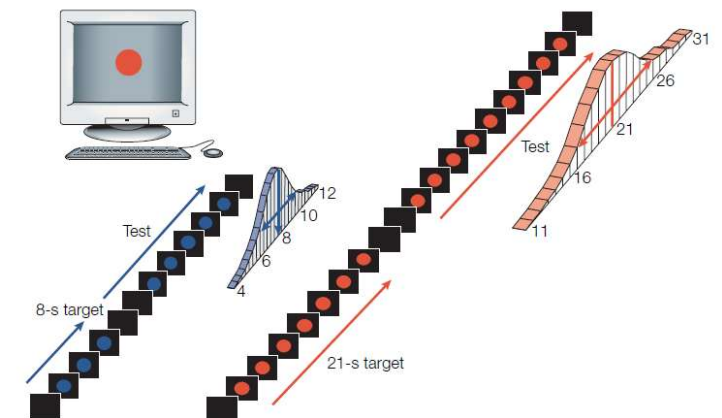
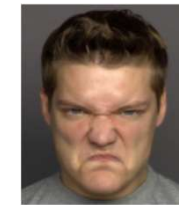
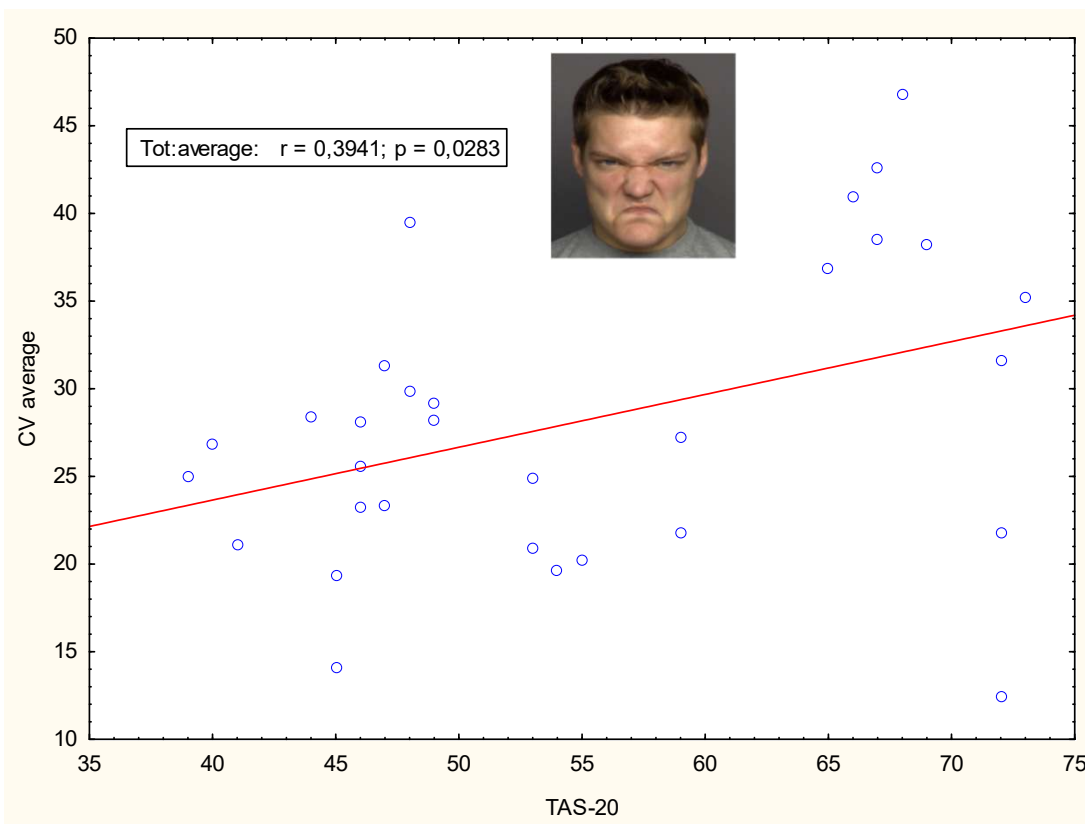
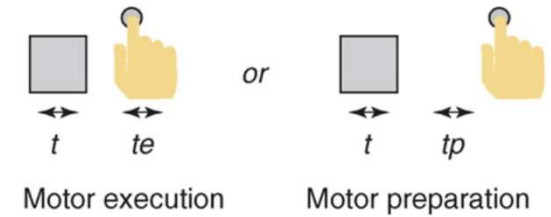


RESEARCH ARTICLE

Evidence of abnormal scalar timing property in alexithymia

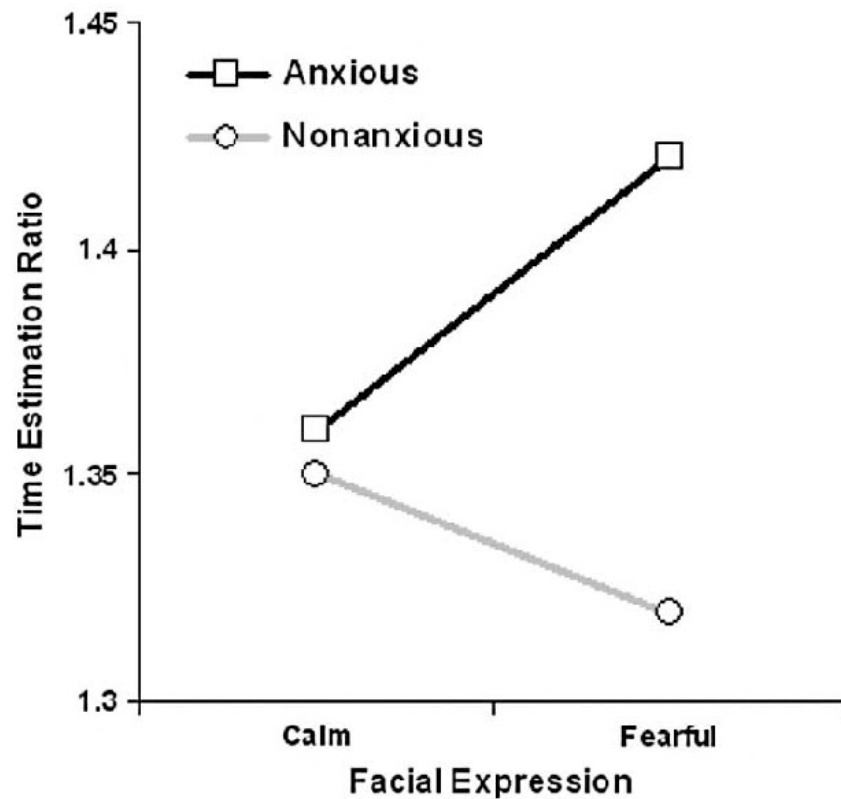
Carmelo Mario Vicario^{1*}, Vito Scavone¹, Chiara Lucifora², Alessandra Falzone¹, Giovanni Pioggia³, Sebastiano Gangemi⁴, Giuseppe Craparo⁵, Gabriella Martino⁴

(b) Temporal reproduction

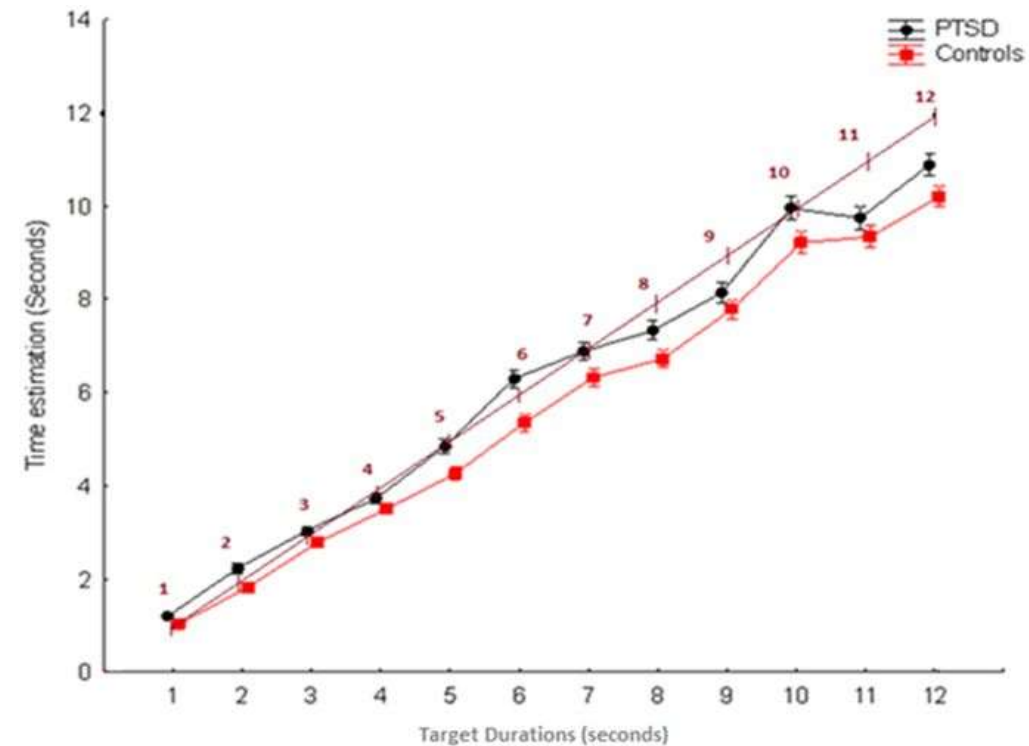


Vicario et al., 2023, PlosOne

Mood: Anxiety vs. PTSD



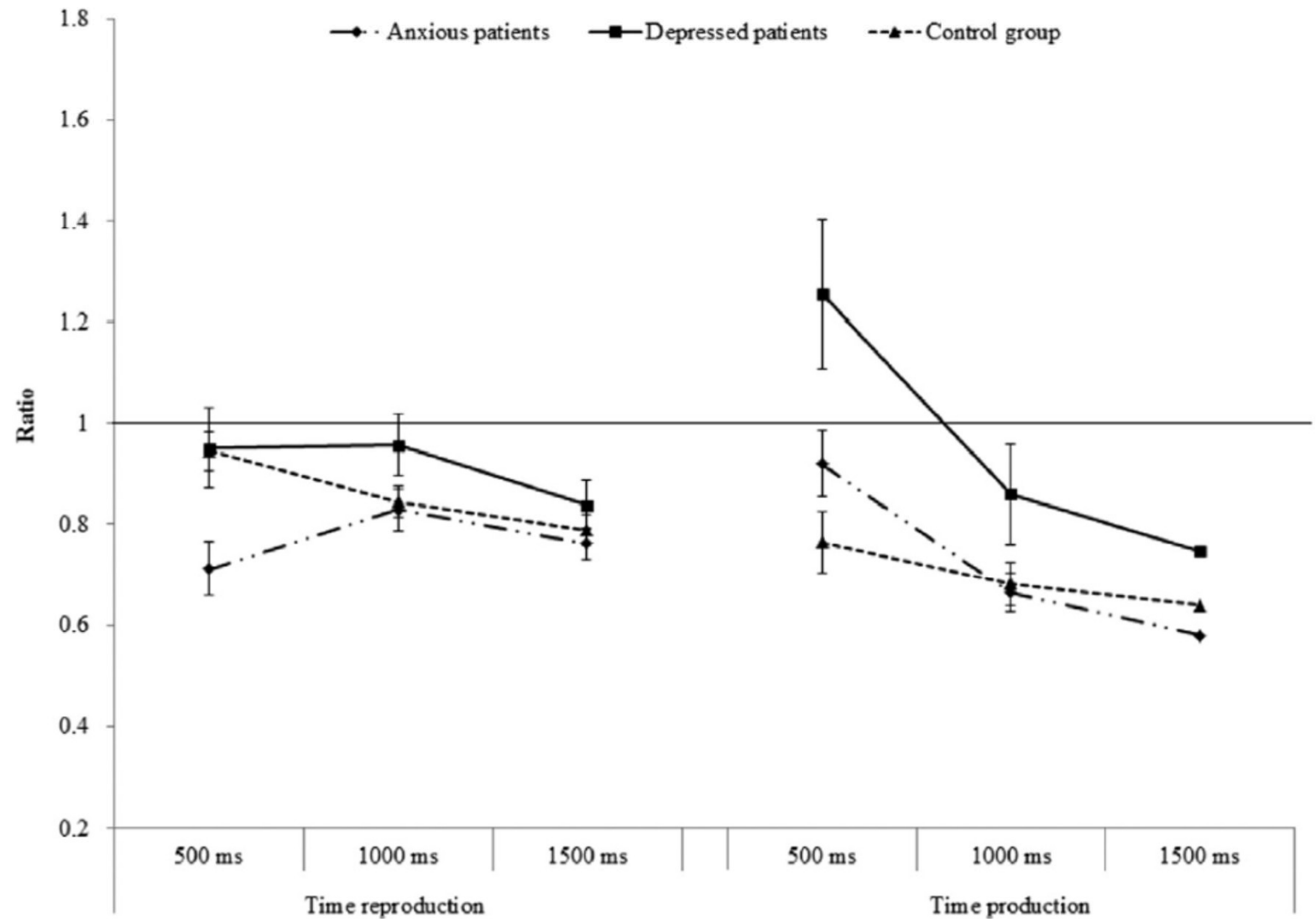
Yair Bar-Haim et al., 2010, Cogn Emotion



Vicario and Felmingham, 2018, Scientific Reports

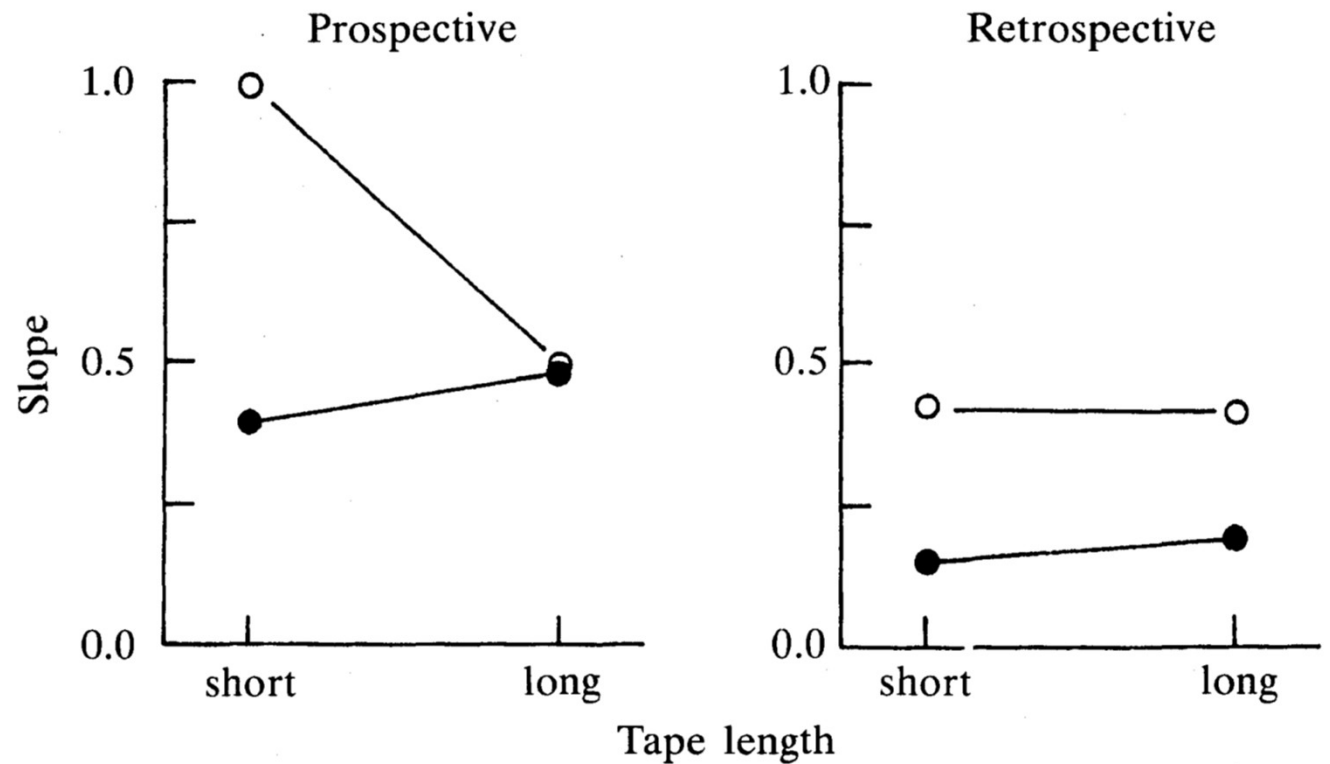
Mood: Anxiety vs. Depression

G. Mioni et al. / Journal of Affective Disorders 196 (2016) 154–163



Attention and interference in prospective and retrospective timing[†]

The allocation of processing resources (attention)



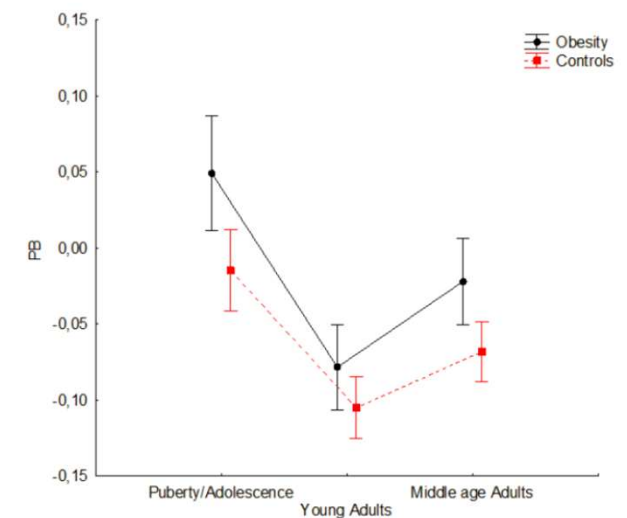
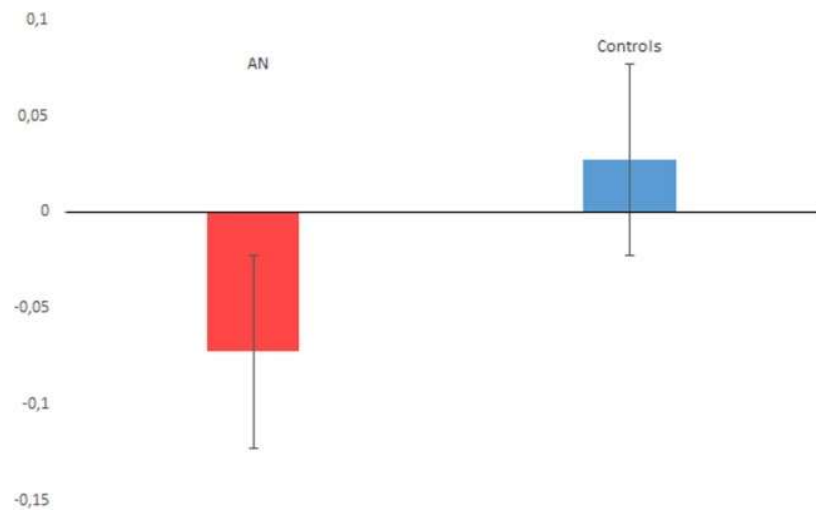
The allocation of processing resources (attention deficits)



Puyjarinet et al., 2017, Scientific Reports

Alterazioni del sistema ricompensa e stima del tempo

Eating habits and timing deficits





Correlati neurali della stima del tempo

Il cervelletto

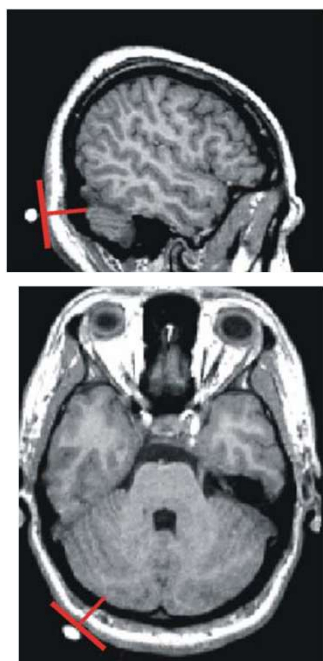
(sub-second durations)

Exp Brain Res (2007) 179:291–299
DOI 10.1007/s00221-006-0791-1

RESEARCH ARTICLE

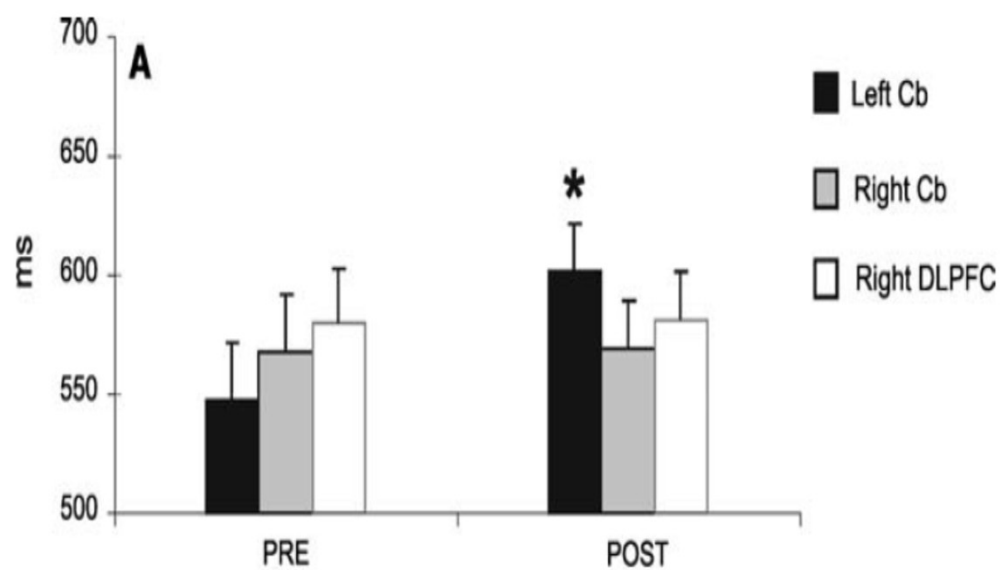
Repetitive TMS of cerebellum interferes with millisecond time processing

ICerebellum



Exp Brain Res (2007) 179:291–299

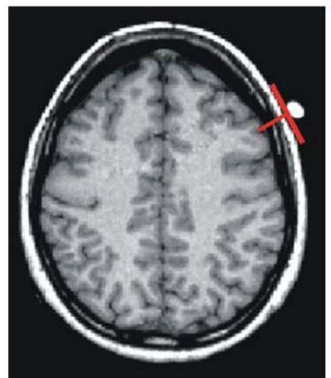
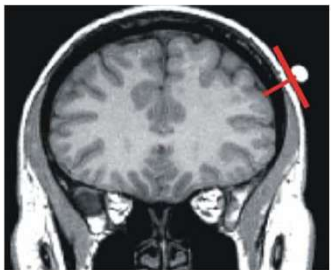
Time reproduction task



Il lobo frontale

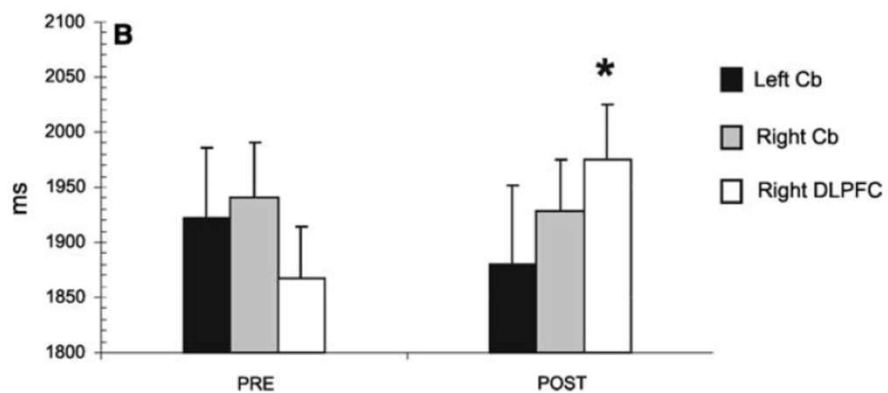
(supra-second durations)

rDLPFC

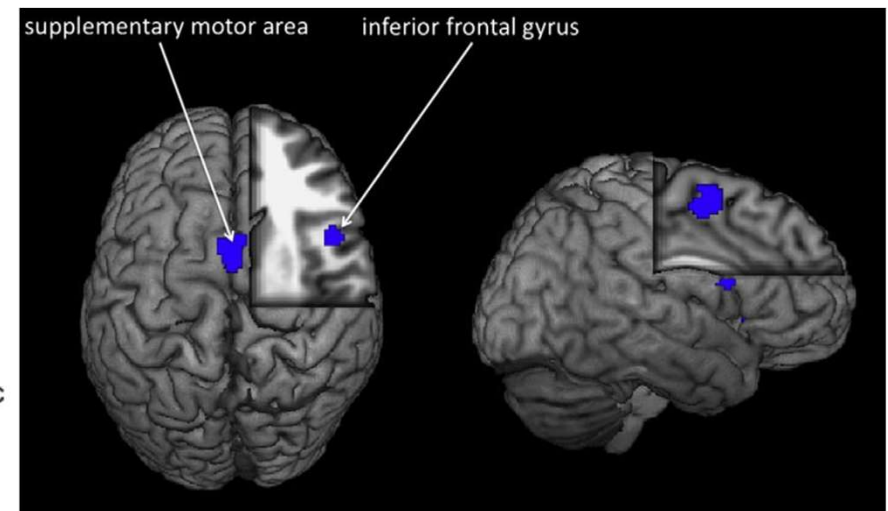


Exp Brain Res (2007) 179:291–299

Time reproduction task



SMA e IFG (both sub and supra)



M. Wiener et al. / NeuroImage 49 (2010) 1728–1740

Selective deficit of time perception in a patient with right prefrontal cortex lesion

*Giacomo Koch, MD; Massimiliano Oliveri, MD, PhD;
Giovanni A. Carlesimo, MD, PhD; and Carlo Caltagirone, MD*

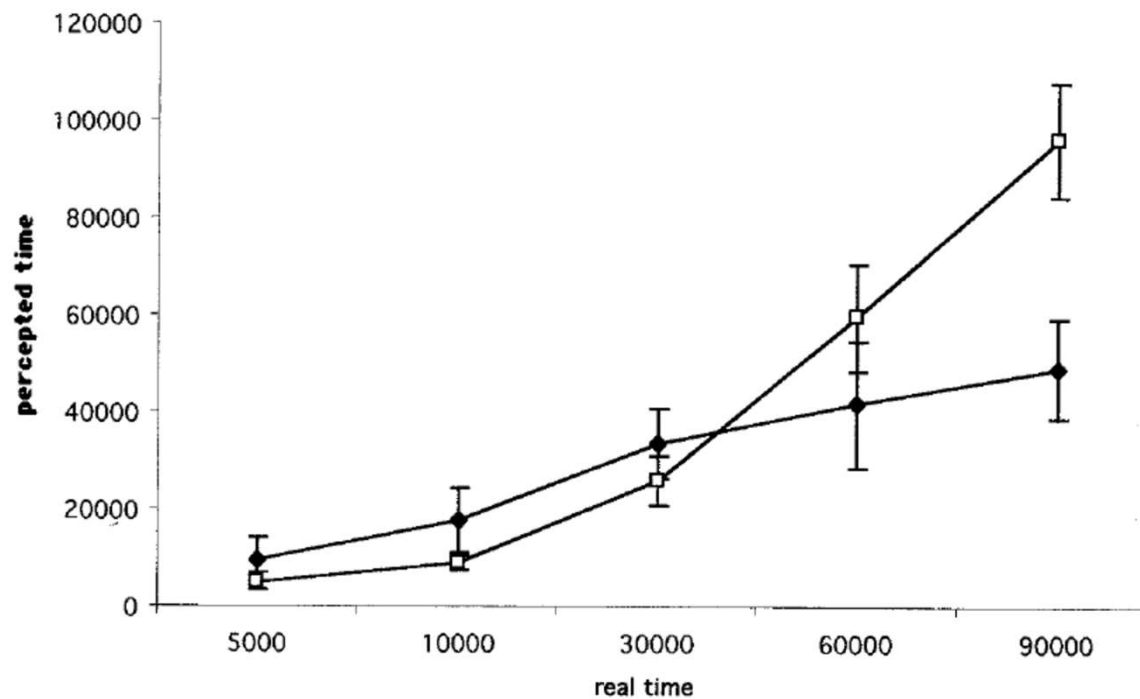


Figure. Mean perception of time intervals in patient (black circles) and control subjects (white squares). Values in the two axes are expressed in milliseconds. Error bars indicate 1 SEM.

Il lobo parietale (suprasecond durations)

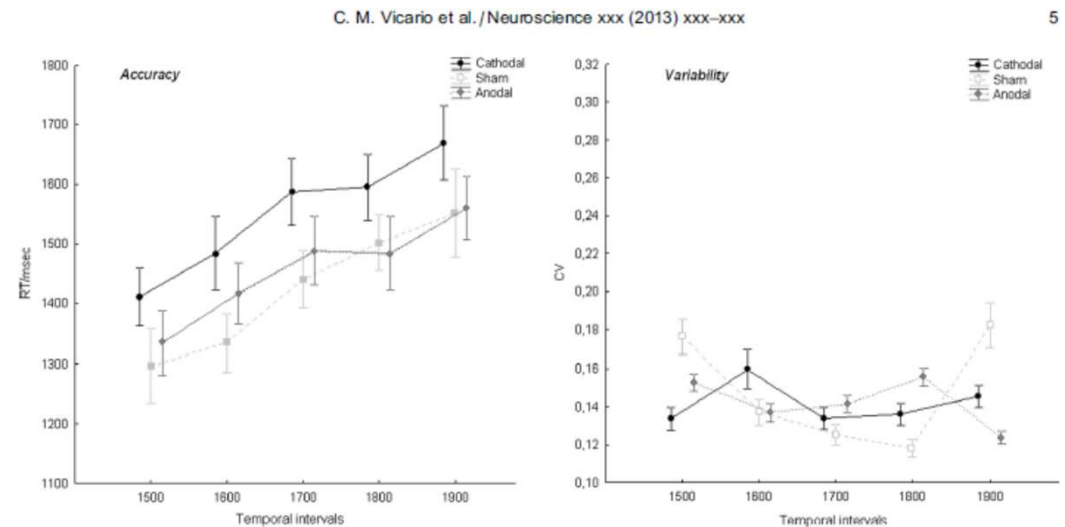
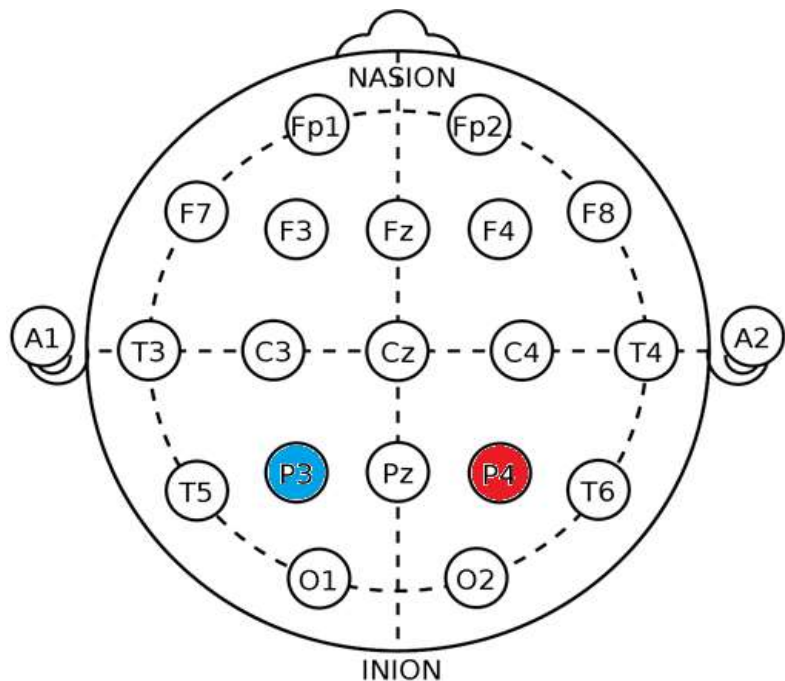
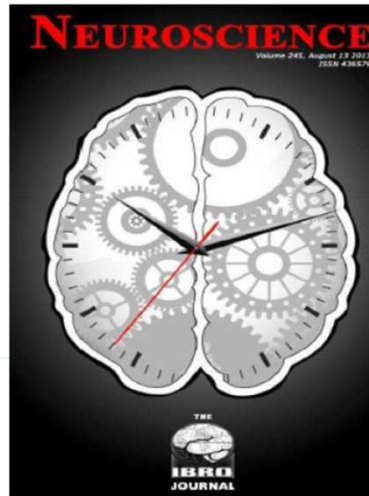


Fig. 2. Stimulation of right PPC. *Accuracy*: Means Reaction Time (RT) values expressed in millisecond during the reproduction of supra-second intervals. RT values result globally higher under cathodal stimulation, compared with sham stimulation. *Variability*: coefficient of variation scores during reproduction of supra-second intervals. Standard deviation values were divided for mean RT values. Vertical bars indicate standard error mean (SEM).

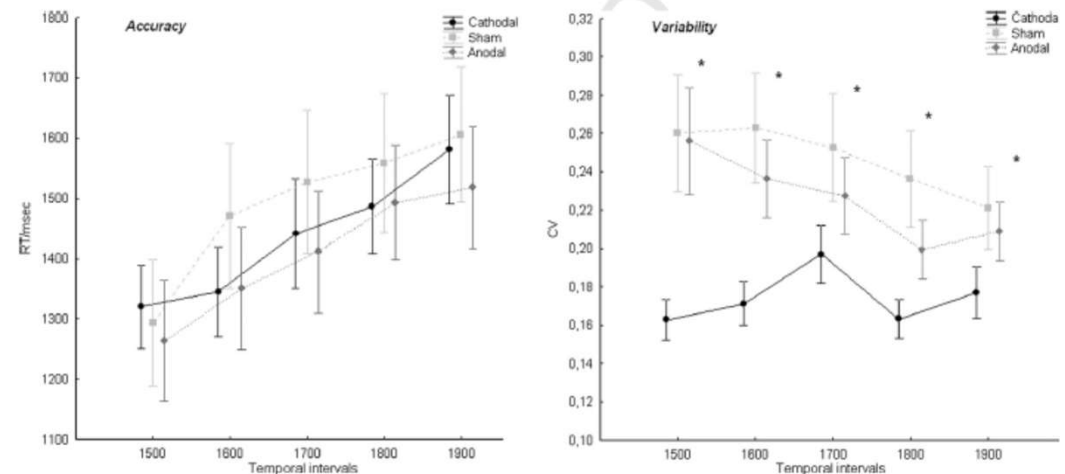


Fig. 3. Stimulation of left PPC. *Accuracy*: Means Reaction Time (RT) values expressed in millisecond during the reproduction of supra-second intervals. *Variability*: Coefficient of variation scores during the reproduction of supra-second intervals. Standard deviation values were divided for mean RT values. Vertical bars indicate standard error mean (SEM). The “*” symbol indicates significant post hoc interactions.

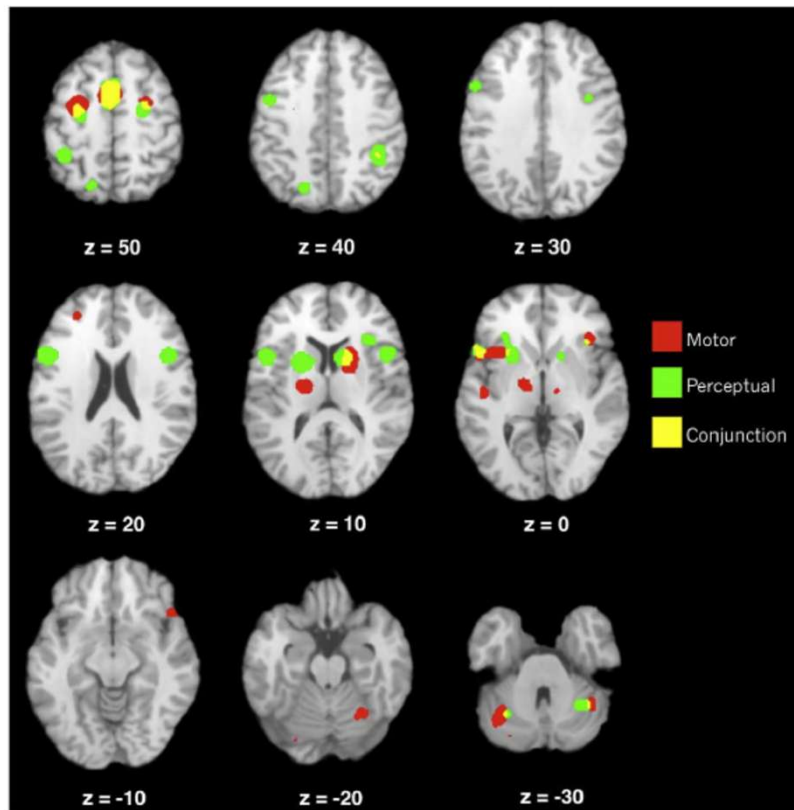


The image of time: A voxel-wise meta-analysis

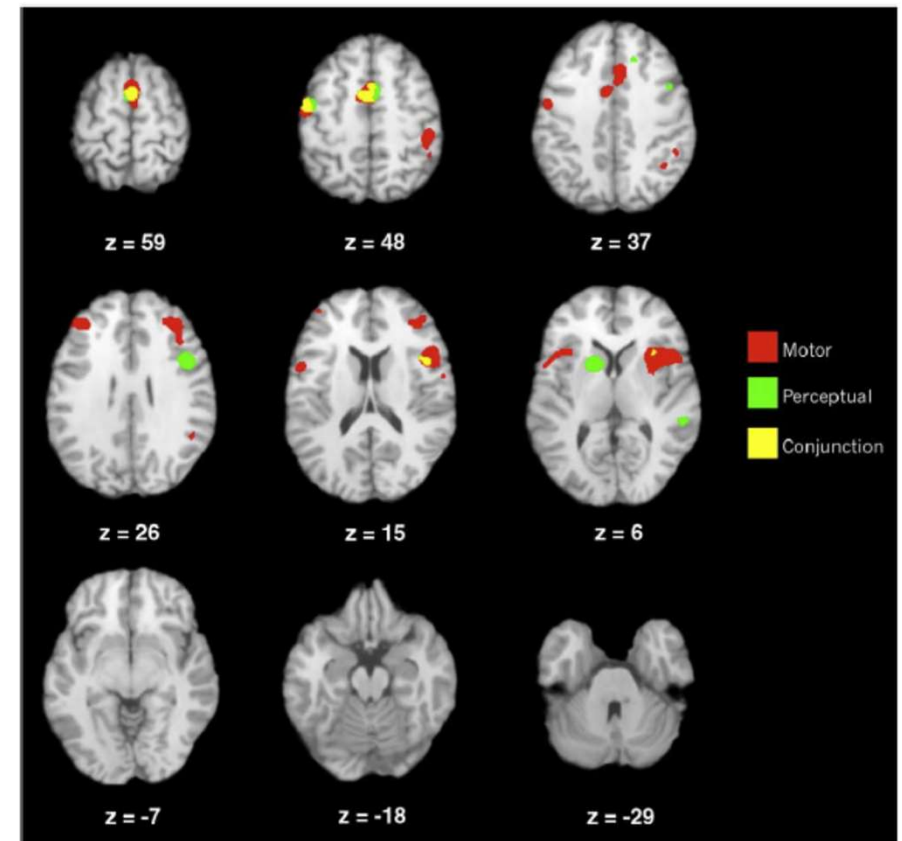
Martin Wiener^a, Peter Turkeltaub^b, H.B. Coslett^{b,*}

Sub-second durations

M. Wiener et al. / NeuroImage 49 (2010) 1728–1740

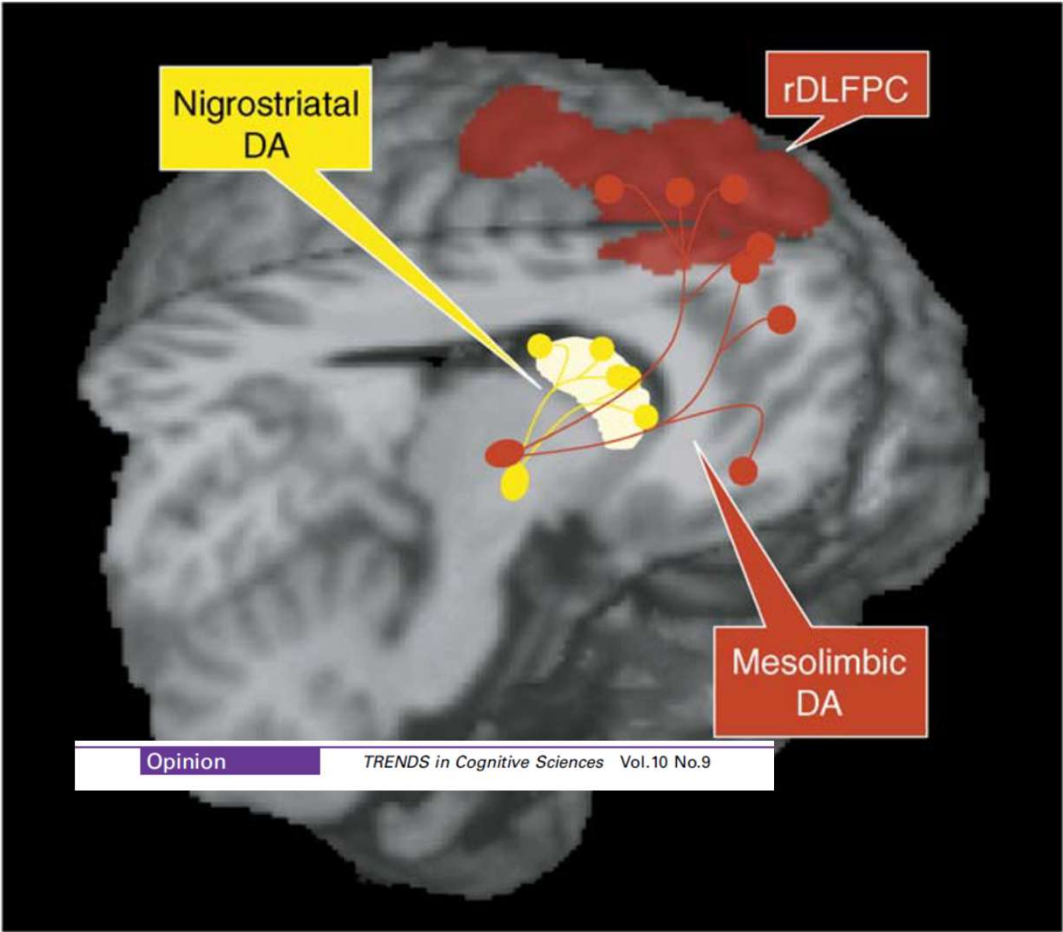


Supra-second durations



Una visione
d'insieme

I gangli della base



	Time processing deficit	Timing Pattern
Schizophrenia	Confirmed	Overestimation
Depression	Confirmed	Not conclusive
Anxiety	Confirmed	Underestimation
PTSD	Confirmed	Overestimation
Anorexia Nervosa	Confirmed	Underestimation
Hyperphagia	Confirmed	Overestimation
ADHD	Confirmed	Underestimation
Tourette	Confirmed	Overestimation
Autism	Confirmed	Underestimation
Parkinson	Confirmed	Underestimation
Dystonia	Confirmed	no difference with the control group
Essential Tremor	Confirmed	Underestimation

High DA, Shen et al. 2012

Low DA, Vicario et al., 2017

Low DA, Robinson et al., 2006

High DA, Hoexter et al., 2012

Low DA, Vicario et al., 2017

High DA, Volkow et al. 2009

Low DA, Volkow et al., 2007

High DA, DEsens et al. 2013

Low DA, Scott-Van Zeeland et al., 2010

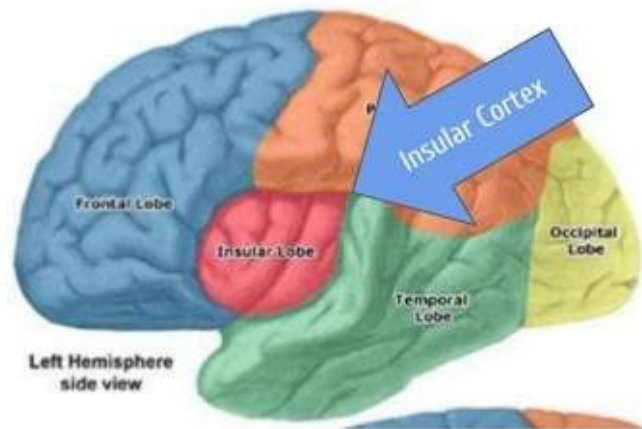
Low DA, Vicario et al., 2013

Low DA, Karimi, Perlmutter, 2015

Results not conclusive

L'insula

The Insular Cortex



Vicario et al., 2020. *Front. Psychol*

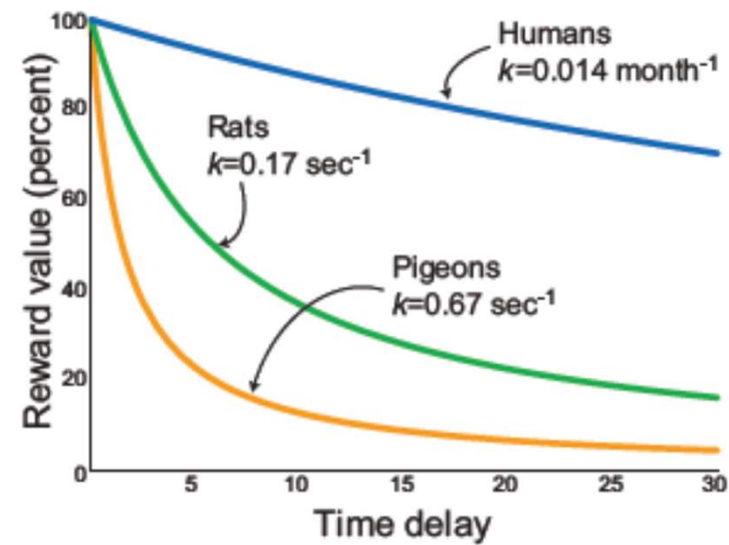
	Time processing deficit	Timing Pattern	Interoceptive alterations	Insula response	Task
<i>Schizophrenia</i>	Confirmed	Overestimation	Confirmed	Reduced	Timing
<i>Depression</i>	Confirmed	Not conclusive	Confirmed	Not conclusive	Affective
<i>Anxiety</i>	Confirmed	Underestimation	Confirmed	Increased	Affective
<i>PTSD</i>	Confirmed	Overestimation	Confirmed	Reduced	Affective
<i>Anorexia Nervosa</i>	Confirmed	Underestimation	Confirmed	Increased	Reward processing
<i>Hyperphagia</i>	Confirmed	Overestimation	Confirmed	Reduced	Reward processing
<i>ADHD</i>	Confirmed	Underestimation	Confirmed	Reduced	Timing
<i>Tourette</i>	Confirmed	Overestimation	Confirmed	Increased	Clinical*
<i>Autism</i>	Confirmed	Underestimation	Confirmed	Reduced	Affective
<i>Parkinson</i>	Confirmed	Underestimation	Confirmed	Reduced	Timing
<i>Dystonia</i>	Confirmed	no difference with the control group	Confirmed	Reduced	Clinical**
<i>Essential Tremor</i>	Confirmed	Underestimation	NA	Reduced	Clinical***

Delay Reward
Discounting: se il tempo
definisce il valore di una
ricompensa



Relazione tra tempo trascorso e valore di una ricompensa

Il valore attribuito ad una ricompensa si riduce col passare del tempo

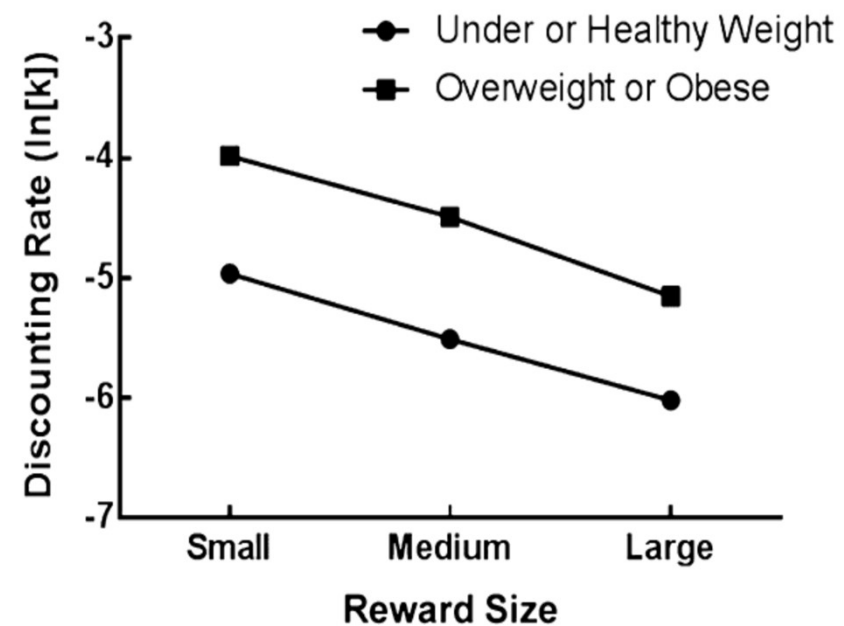
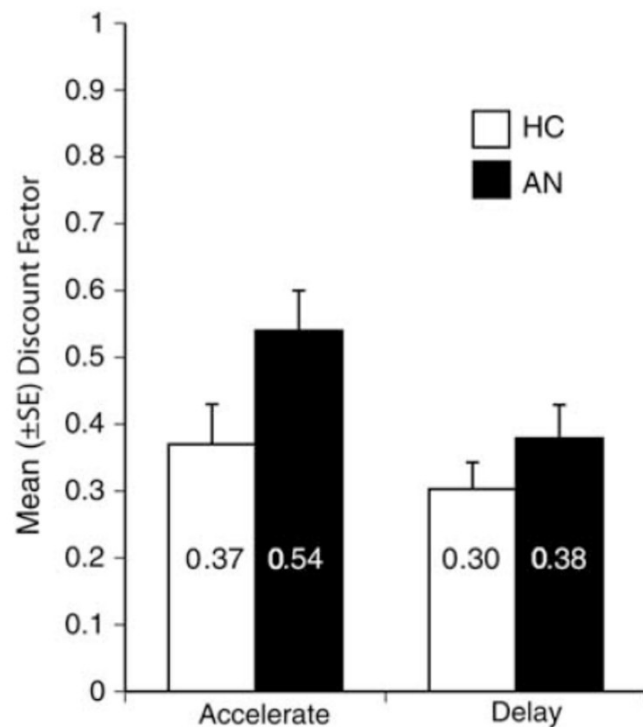


Rachlin Raineri Cross 1991

Temporal discounting e alterazioni del reward system: il confronto tra due condizioni cliniche antitetiche

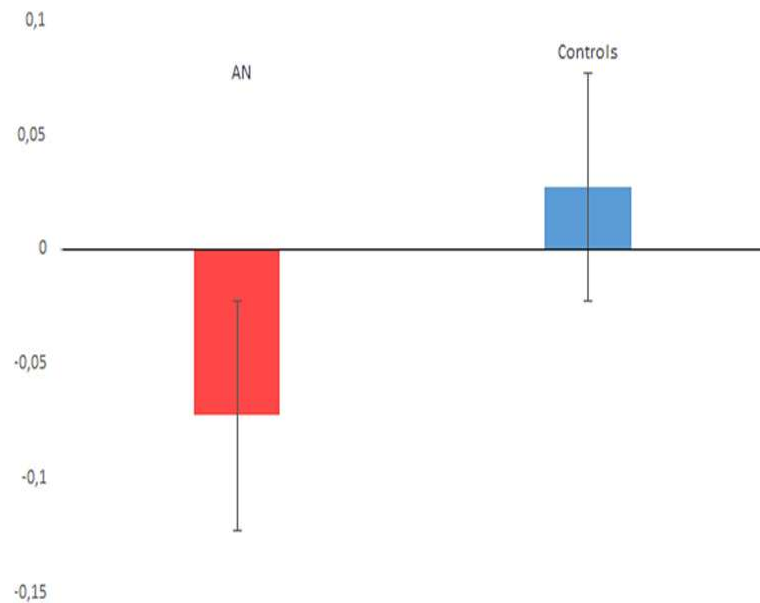
Anoressia Nervosa (discount less):

Obesita' (discount more)

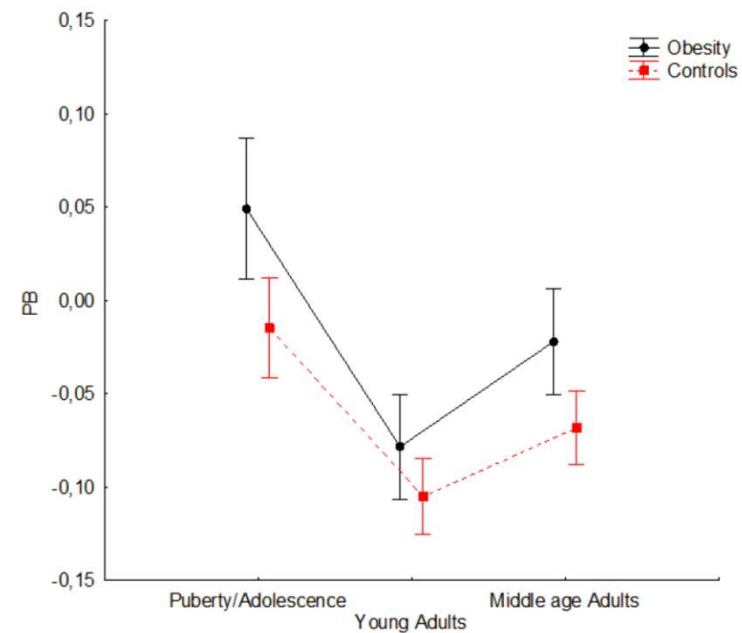


Puo' l'alterazione del temporal discounting essere spiegata dal pattern di stima temporale?

Anoressia Nervosa: sottostima il tempo



Obesita': sovraestima il tempo



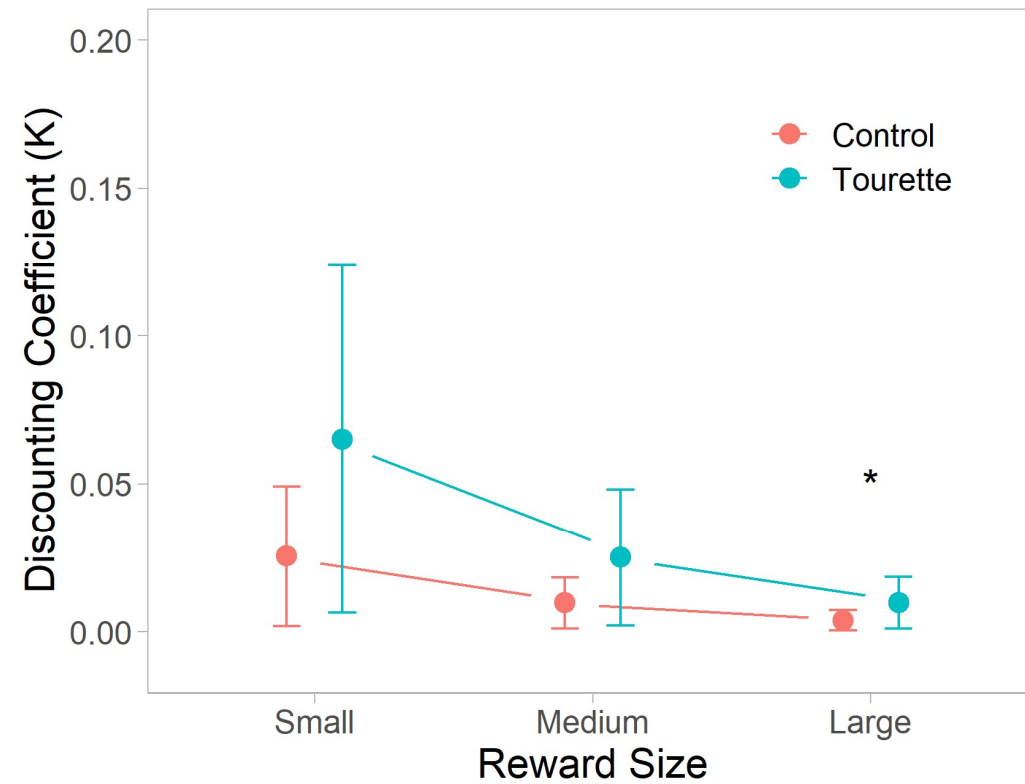
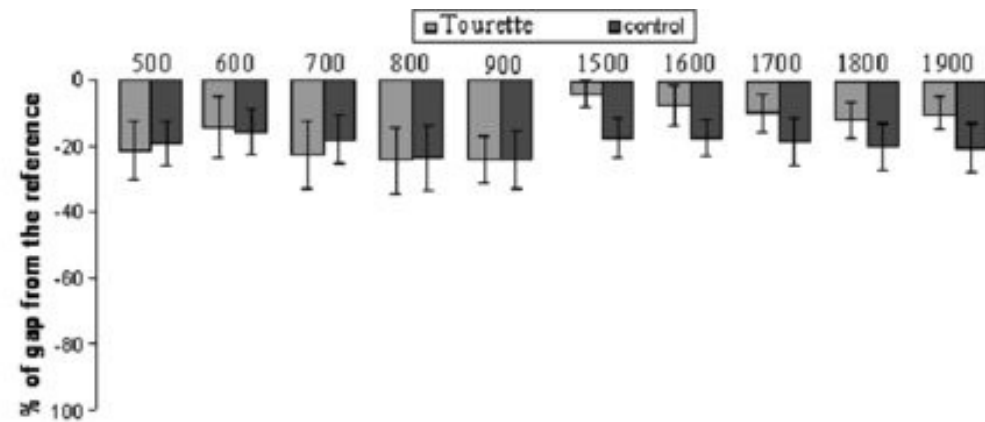


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Time processing in children with Tourette's syndrome

sovrastima over second durations



Reduced delay discounting

Table 2. Meta-analytic Results by Disorder Category

Disorder	No. of Effect Sizes	Total No. of Unique Individuals	Hedges g Effect Size	P Value	95% CI	OSR	Cochran Q Test of Homogeneity	Cochran Q Test P Value	I ² Statistic	SD of Aggregate Effect Size, τ
Major depressive disorder	7	420	0.37	.002	0.14 to 0.61	0.29 to 0.44	8.31	.22	27.82	0.17
Schizophrenia	12	766	0.46	.004	0.14 to 0.77	0.34 to 0.53	52.97	<.001	79.23	0.48
Borderline personality disorder	8	451	0.60	<.001	0.32 to 0.87	0.51 to 0.67	15.74	.028	55.53	0.29
Bipolar disorder	4	349	0.68	<.001	0.37 to 0.98	0.55 to 0.78	4.91	.18	38.853	0.20
Obsessive-compulsive disorder	5	371	0.30	.002	0.11 to 0.49	0.20 to 0.34	3.77	.44	0.00	0.00
Bulimia nervosa	4	183	0.41	.001	0.17 to 0.65	0.31 to 0.47	1.85	.60	0.00	0.00
Binge-eating disorder	7	1483	0.34	.001	0.13 to 0.56	0.29 to 0.45	10.63	.10	43.53	0.18
Anorexia nervosa	10	655	-0.30	<.001	-0.46 to -0.14	-0.27 to -0.35	10.31	.33	12.73	0.09

Abbreviations: I², proportion of variability from heterogeneity; OSR, one-study removed, or range of effect sizes obtained from OSR jackknife analysis.

The delay reward discounting pattern

Steep delay discounting

Overestimation-
Mioni et al

Steep delay discounting

Reduced delay discounting

Steep delay discounting

Reduced delay discounting

Steep delay discounting

Steep discounting

Steep delay discounting

Normal

Steep discounting in impulsivity/comp sample

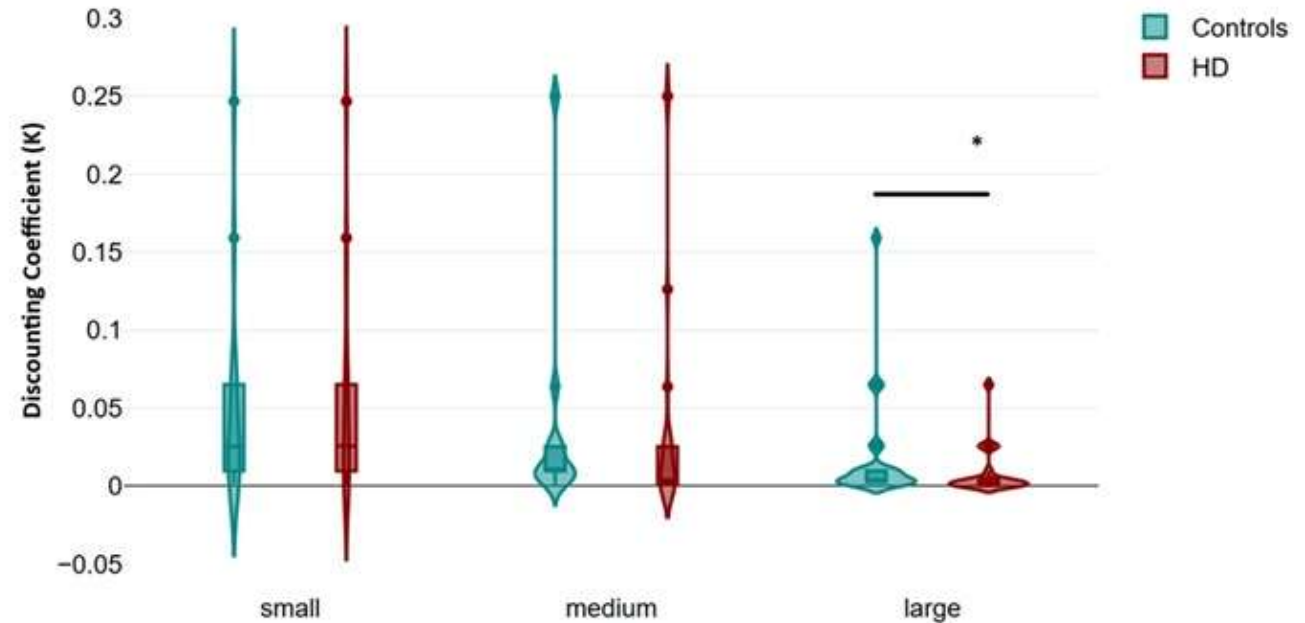
NA

NA

	Time processing deficit	Timing Pattern
<i>Schizophrenia</i>	Confirmed	Overestimation
<i>Depression</i>	Confirmed	Not conclusive
<i>Anxiety</i>	Confirmed	Underestimation
<i>PTSD</i>	Confirmed	Overestimation
<i>Anorexia Nervosa</i>	Confirmed	Underestimation
<i>Hyperphagia</i>	Confirmed	Overestimation
<i>ADHD</i>	Confirmed	Underestimation
<i>Tourette</i>	Confirmed	Overestimation
<i>Autism</i>	Confirmed	Underestimation
<i>Parkinson</i>	Confirmed	Underestimation
<i>Dystonia</i>	Confirmed	no difference with the control group
<i>Essential Tremor</i>	Confirmed	Underestimation

Does delay reward discounting predict timing performance (and vice-versa)?

Reduced temporal discounting in Huntington's disease?



This finding is consistent with observation in obsessive-compulsive personality disorder, whose symptoms may also affect HD patients⁹.

Time performance as an index of clinical improvement?

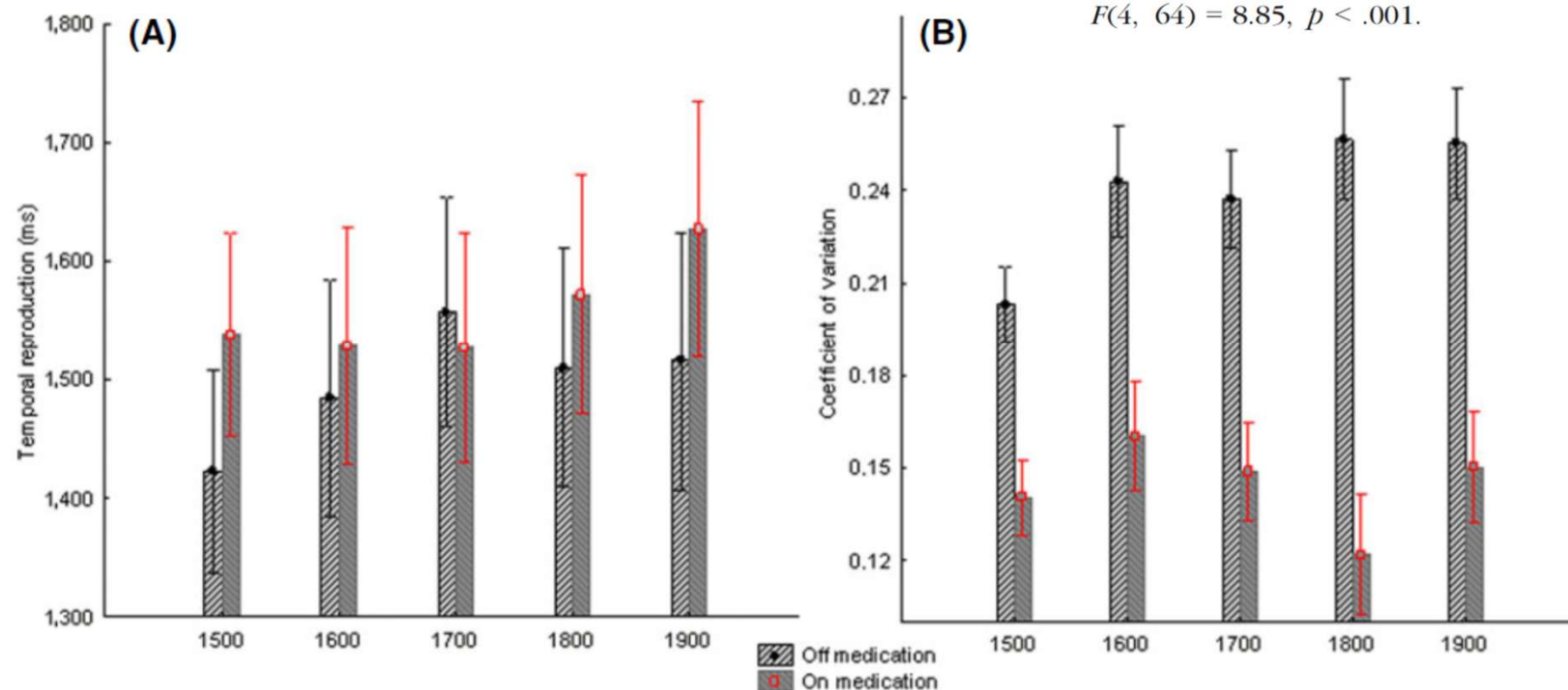
Journal of Neuropsychology (2015)
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Timing recalibration in childhood Tourette syndrome associated with persistent pimozide treatment



- [Philip Zimbardo: The psychology of time | TED Talk](#)

