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What's on a subjective evaluation of time? Dissociating premotor and motor components in RT task reveals the building blocks of time metacognition

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Introduction

- Metacognition refers to the subjective evaluation of our own cognitive performances and processes, and can be crucial to regulate behavior.
- Metacognition in the time domain remains poorly investigated even though temporal information is of great importance for appropriate behaviour.
- When we have to act as fast as possible (i.e reaction time situation), time is implicit but largely contributes to the achievement of the goal.
- Previous study (Corallo et al. 2008) showed that on average, participants have a rather good estimation of their reaction times (RTs).

Question 1 : Is RT estimation really based on temporal information?

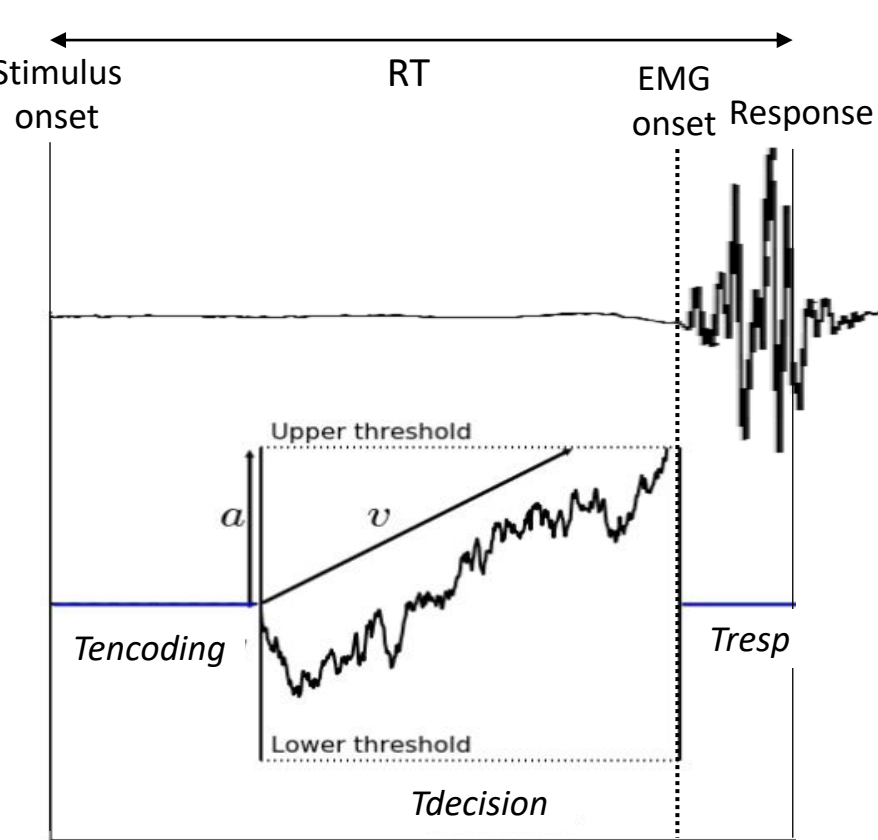


Fig.1 adapted from (Weindel et al. 2021)

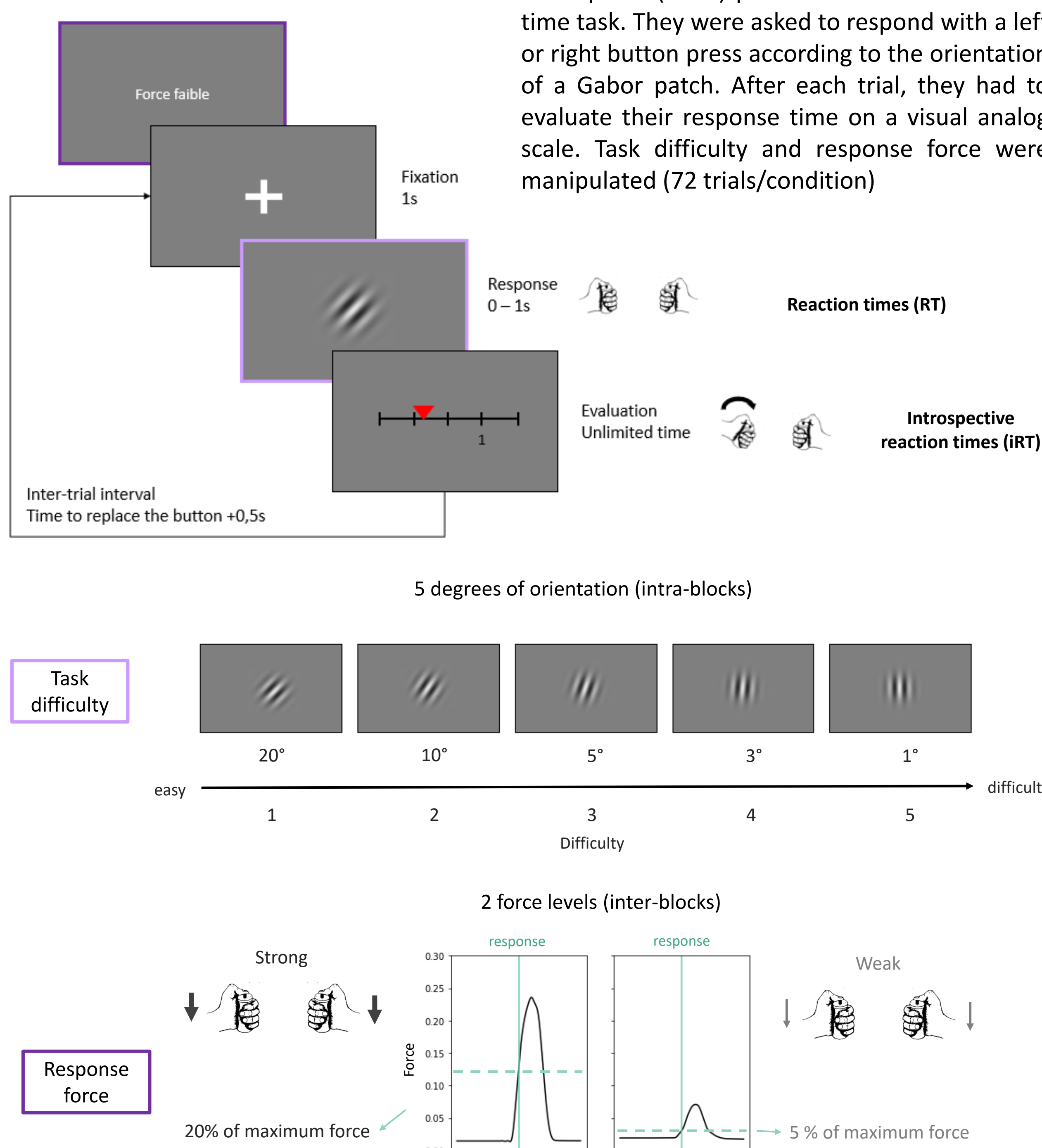
- RTs constitute a widespread measure of the time taken to decide and initiate an appropriate action.
- Many models (e.g. diffusion models) separate RTs into a decision time (*Tdecision*), during which evidence is accumulated until a decision threshold is reached (Fig.1), and a non decision time, composed of encoding time (*Tencoding*) and motor execution time (*Tresp*).
- Motor execution time, which can be measured directly using electromyography (EMG), is almost always ignored even though it is a significant part of RTs variability.
- We do not know if and to what extent this motor time contributes to RTs subjective evaluation.

Question 2 : What is the contribution of decision and non decision time in RT estimation?

Materials and Methods

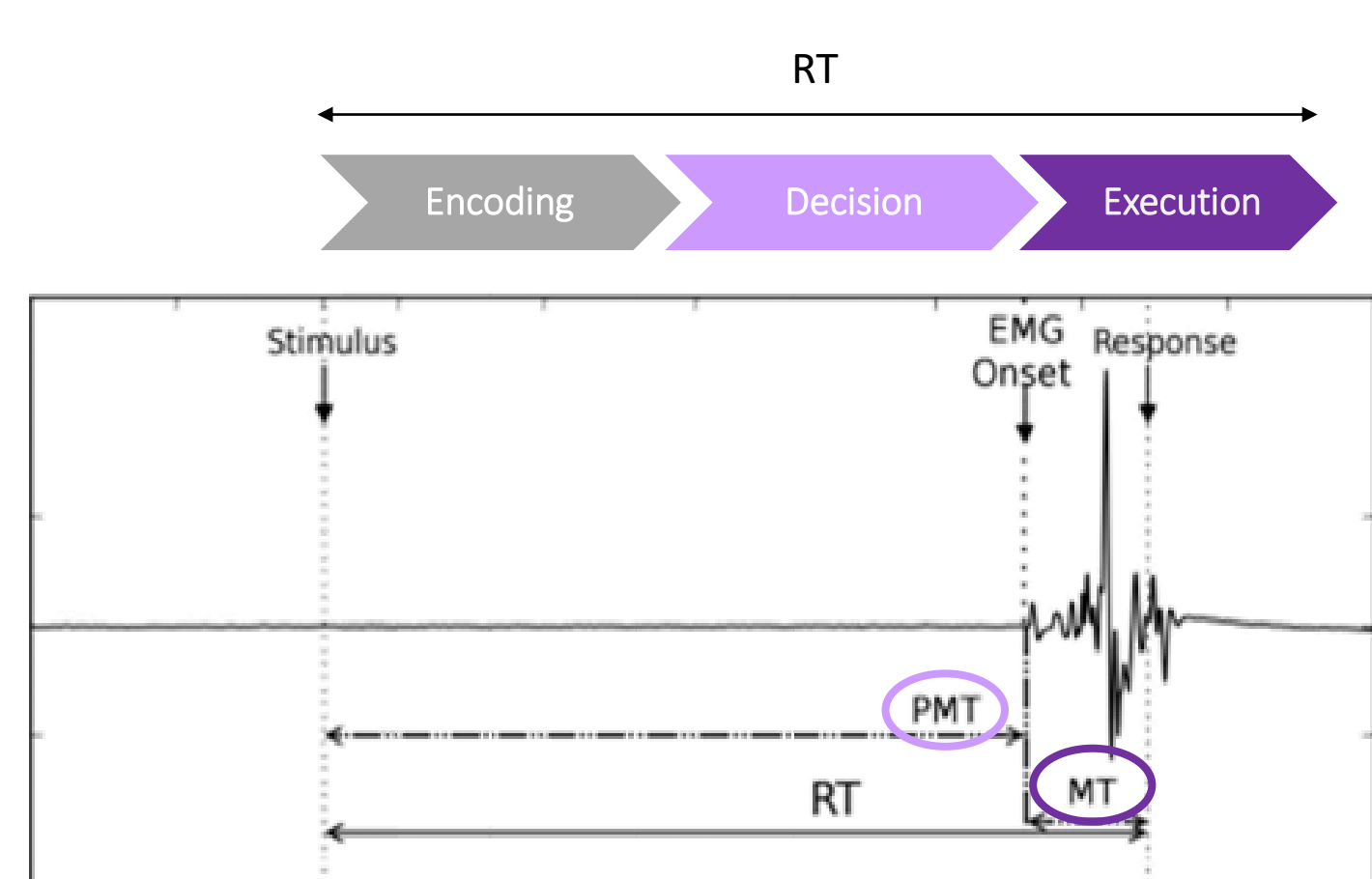
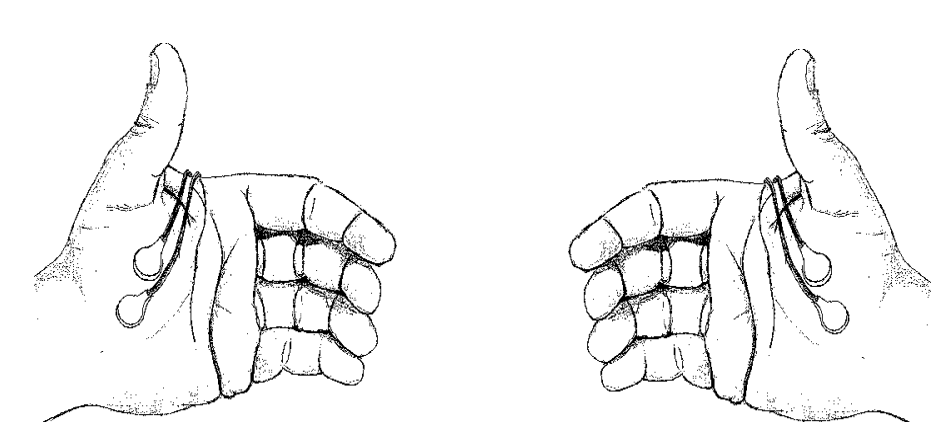
Behavioral task

Participants (n=30) performed a choice reaction time task. They were asked to respond with a left or right button press according to the orientation of a Gabor patch. After each trial, they had to evaluate their response time on a visual analog scale. Task difficulty and response force were manipulated (72 trials/condition)



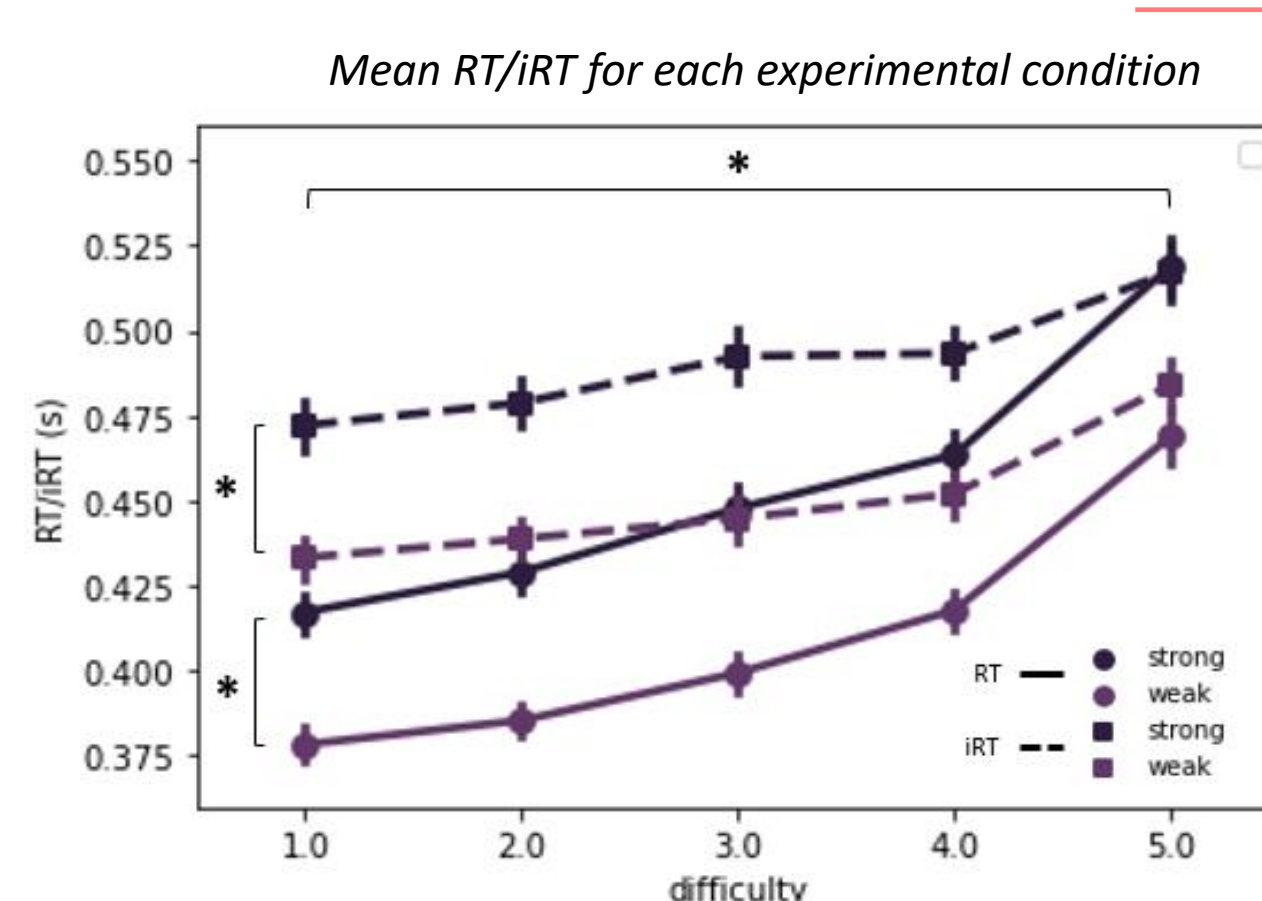
EMG recording

EMG was recorded from *flexor pollicis brevis* of both hands. It allowed to fractionate reactions times into premotor (PMT) and motor (MT) times, reflecting respectively the decision and the motor execution processes.



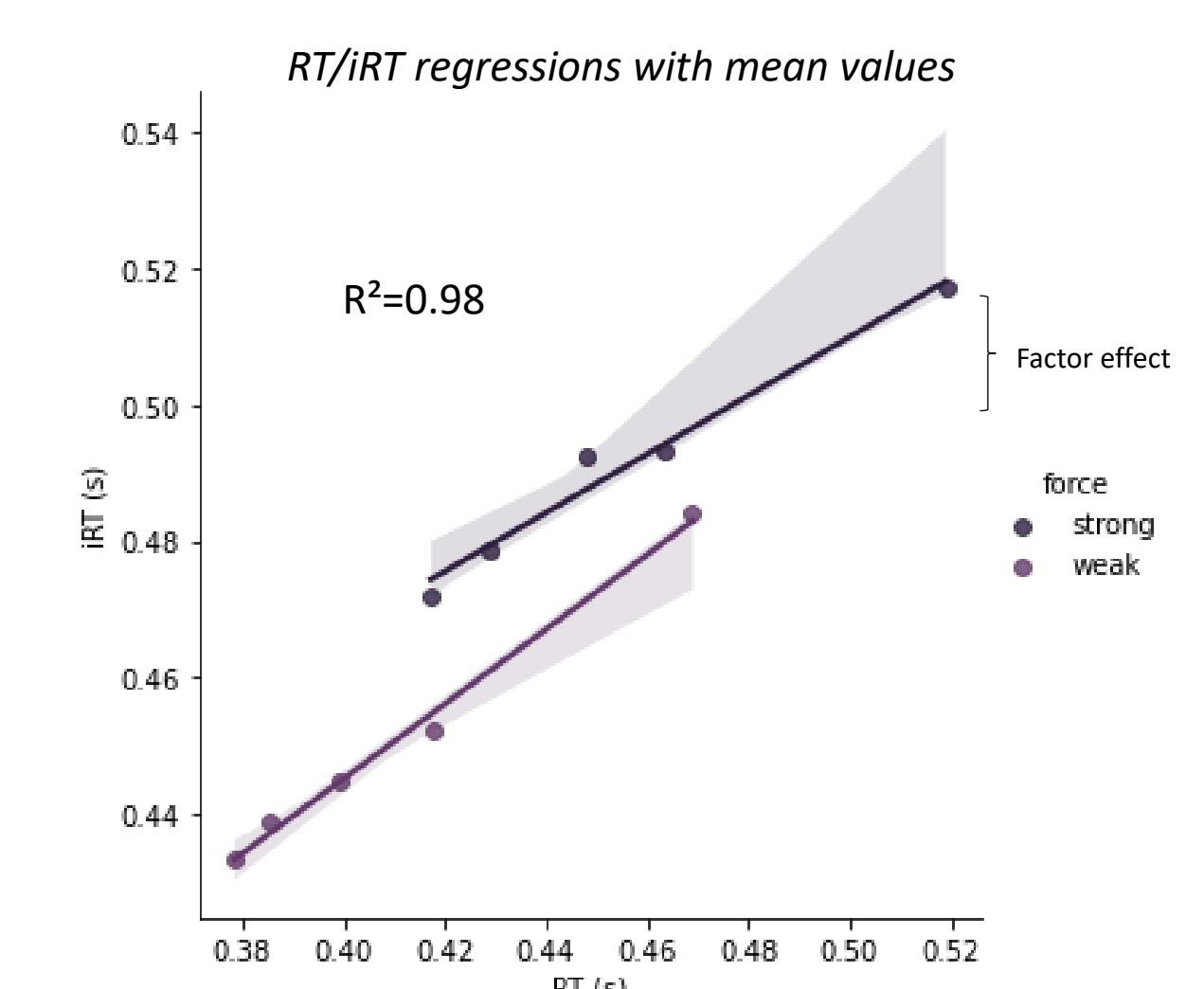
Results

Behavioral results



Same modulation of RT and iRT by experimental conditions

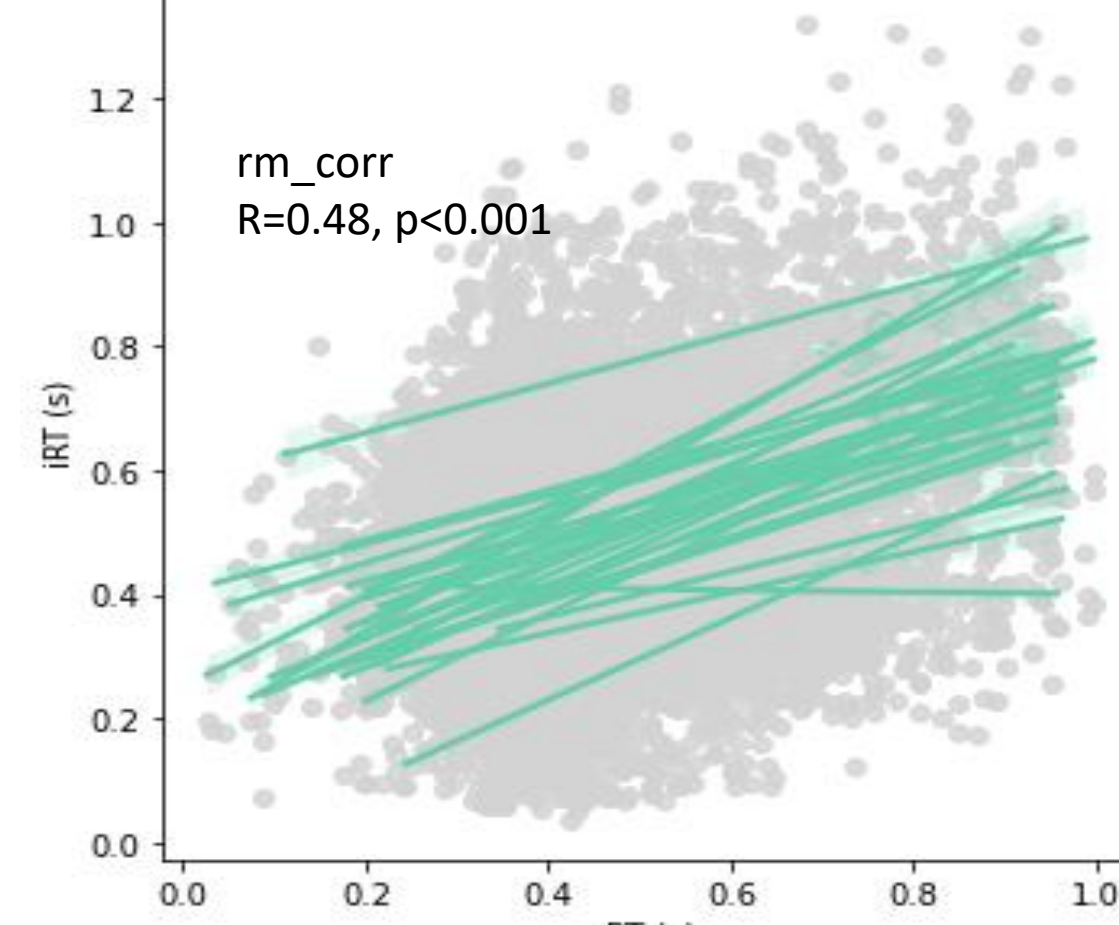
force x difficulty ANOVAs
RT : force ($F(1,29)=53.46, p<0.001$), difficulty ($F(4,116)=140.54, p<0.001$), no interaction
iRT : force ($F(1,29)=16.33, p<0.001$), difficulty ($F(4,116)=21.72, p<0.001$), no interaction



RT and force predict iRT

Linear regression model
RT : $\beta = 0.45, p<0.001$, Force : $\beta = -0.07, p<0.05$, no interaction

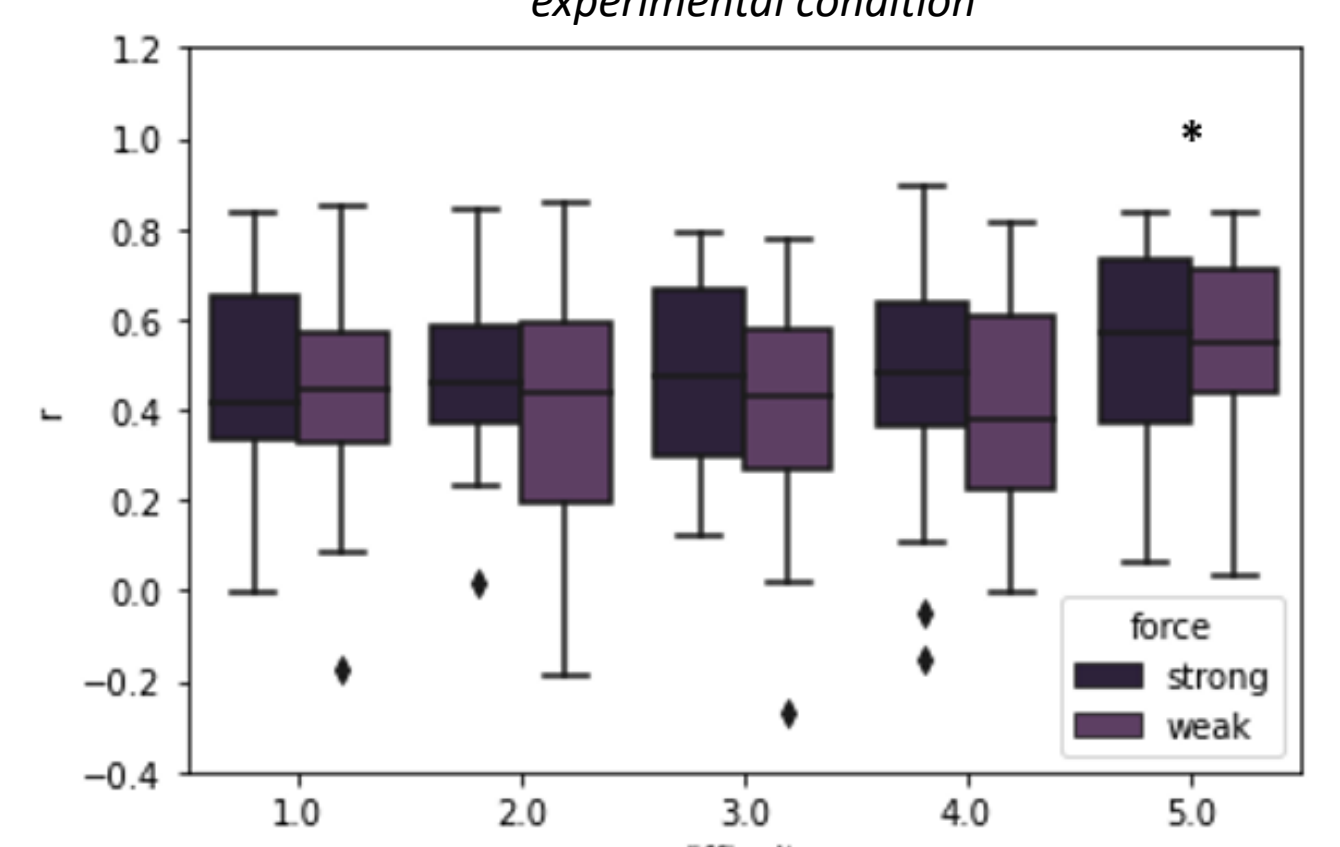
Individual RT/iRT regressions



The vast majority of subjects have a positive correlation between RT and iRT

range=-.02-.80, M=0.51, SD=0.17

Mean correlation coefficients for each experimental condition

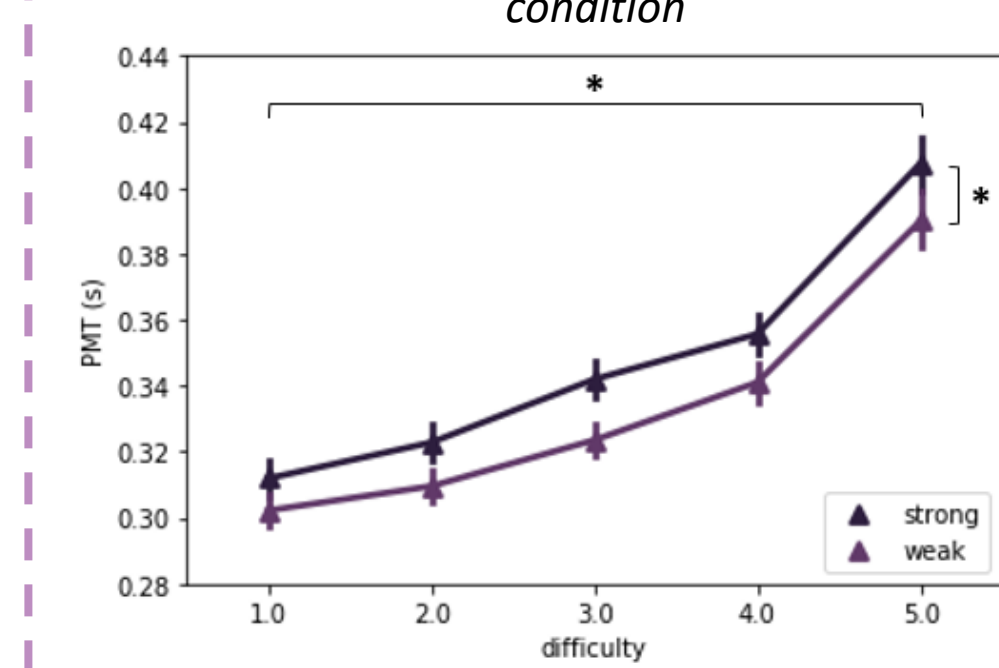


Positive correlations between iRT and RT within each experimental condition

range=-.27-.90, M=0.46, SD=0.22

EMG results

Mean PMT and MT for each experimental condition

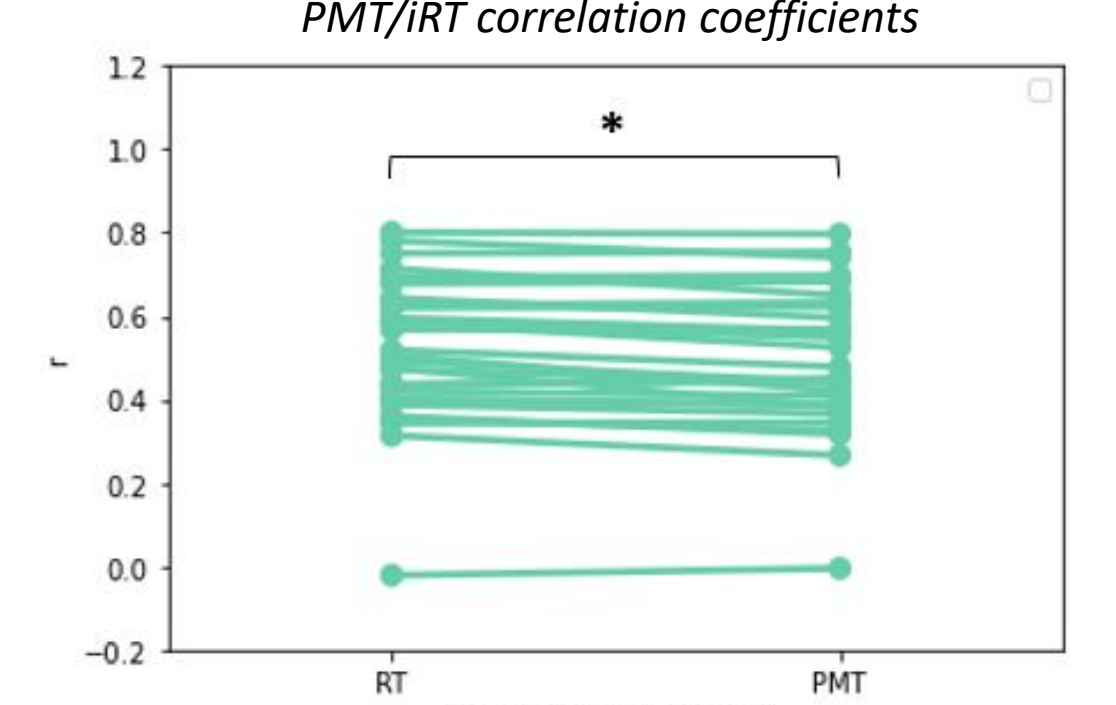


Force x difficulty ANOVAs

PMT : force ($F(1, 29)=10.39, p<0.05$), difficulty ($F(4, 116)=131.6, p<0.001$), no interaction

MT : force ($F(1, 29)=123.40, p<0.001$), difficulty ($F(4, 116)=10.82, p<0.001$), no interaction

Individual differences between RT/iRT and PMT/iRT correlation coefficients



Better correlation of iRT with RT than with PMT

Paired t-test on z transformed r values ($t(29)=4.26, p<0.001$)

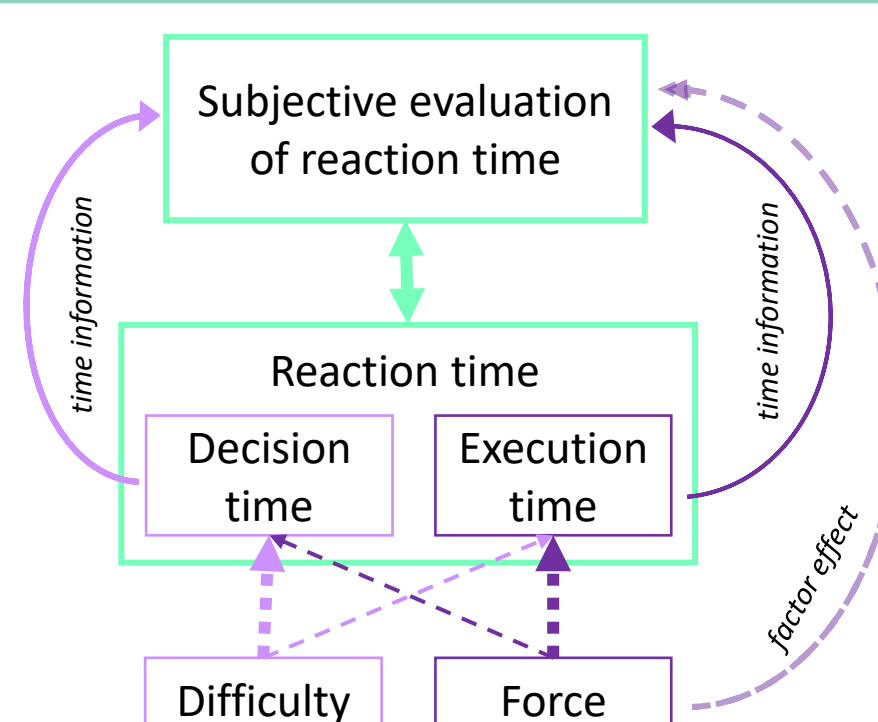
Regression models results

iRT ~ PMT	$R^2= 0.133$	PMT $\beta =0.42^*$	AIC =-1.975e+04
iRT ~ PMT + MT	$R^2= 0.147$	PMT $\beta =0.42^*$ MT $\beta =0.45^*$	AIC =-2.006e+04

Better prediction of iRT with PMT + MT than with PMT only

Conclusion

- We show that iRT is sensitive to both decisional and non decisional experimental manipulations (e.g. difficulty and force) in the same way as RT.
- RT evaluation was biased by force, meaning that part of this effect is a factor effect.
- But, overall, positive correlations between trial-by-trial RT and iRT show that **participants can reliably estimate their RTs** independently of information linked to experimental conditions.



- RT and iRT increased the same way with force, a factor mainly affecting MT.
- The correlation between RT and iRT was degraded when MT was not taken into account.
- These observations suggest that **non decision time** (at least motor execution time) **also contributes to the subjective evaluation of RT.**