Is confidence a form of internal reward? A Pavlovian conditioning study

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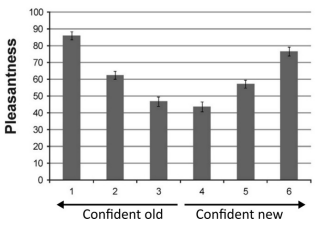
Introduction

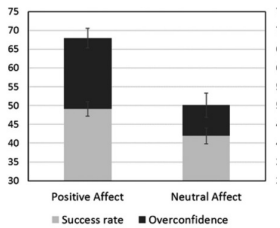
A number of previous findings support the hypothesis that confidence constitutes an internal reward signal.[1,2,3,4]

Phenomenology: confidence feels rewarding



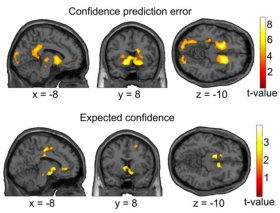
Clos et al 2015, Neuropsychologia

Inverse association: positive affect increases confidence



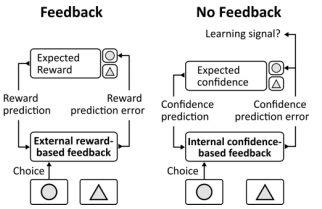
Sidi et al 2018, Cognition & Emotion

Neural basis: shared neural correlates between confidence and reward



Guggenmos et al 2016, eLife

Similar computational mechanisms: confidence prediction error?



Ptaczynski et al 2022, PLOS Computational Biology

In the present study we aim to push this analogy one step further: is it possible to perform Pavlovian conditioning by systematically coupling confidence to previously neutral stimuli?

Methods

Behavior: Subjective reports

Analysed

Skin conductance

Analysed

Heart rate

To be analysed

Pupil dilation

To be analysed

Conditioned stimulus

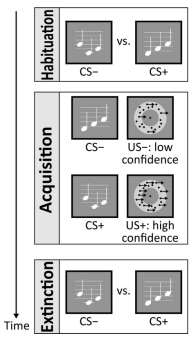
Sounds (short instrumental melodies)

CS-  CS+ 

Unconditioned stimulus

Confidence induced through random dot kinematograms

US-  US+ 



Conditioned stimulus (CS) and unconditioned stimulus (US) presented separatelly

CS occurs before the US

50%: short delay (0.5s)
→ to induce conditioning effects

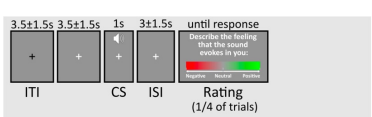
50%: long delay (0.5±1.5s)
→ to analyse skin conductance responses

CS and US presented separatelly

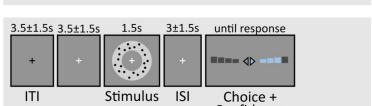
2 sessions
5 blocks each
(1 habituation block, 3 acquisition blocks, 1 extinction block)

Habituation & Extinction

CS only

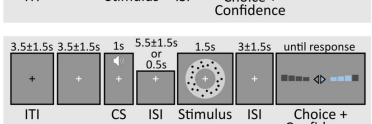


Stimulus only



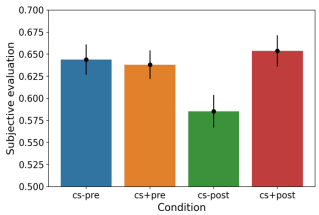
Acquisition

CS + Stimulus



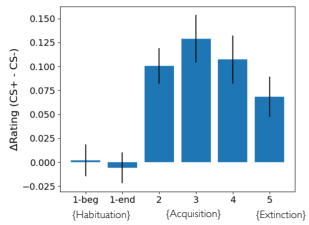
Behavioral effects

N=52



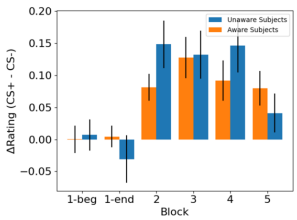
Comparison between pre (habituation) and post (extinction)

Subjective pleasantness of the CS paired with high confidence increased significantly more compared to the CS paired with low confidence ($t(51)=3.4$, $p=0.0011$).



Time-resolved analysis across all blocks (CS+ minus CS-)

- No baseline differences between CS+ and CS-
- Effects on subjective pleasantness emerge already in the first acquisition block
- Measurable reduction in subjective pleasantness in the extinction phase

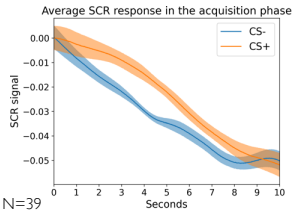


Conditioning in the absence of awareness

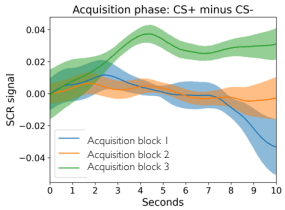
Both the aware and unaware groups showed a similar pattern over the course of the experiment, with no significant difference between the two groups ($t(50)=0.78$, $p=0.43$).

Preliminary GSR Results

N=39



The raw skin conductance response to CS+ and CS-
→ small effect and non-canonical shape



The difference in skin conductance between the CS+ and CS- emerges in the third block of the acquisition phase

Preliminary conclusion

Our study provides first evidence of classical conditioning effects induced by confidence. On the behavioral level, we observed a significant increase in subjective pleasantness of the CS paired with high confidence compared to the CS paired with low confidence. This conditioning effect seems to be independent of awareness of the systematic pairing. Additionally, our skin conductance data showed increased responses to CS+ compared to CS- in the acquisition phase, indicating a conditioning effect.

Open questions

The skin conductance responses to the CS do not take the form of canonical skin conductance response function, indeed there is hardly any visible response. Nevertheless, the response is elevated for CS+ relative to CS-. We appreciate any feedback about these results.

Heart rate and pupil dilation are not yet analysed. We hope that these modalities can clarify whether there is indeed a valid physiological response of "confidence-based" conditioning.

References

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4. Ptaszynski, L. E., Steinecker, I., Sterzer, P., & Guggenmos, M. (2022). The value of confidence: Confidence prediction errors drive value-based learning in the absence of external feedback. PLOS Computational Biology, 18(10), e1010580.

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