

Differences in sense of agency evaluated by intentional binding effect under flat reward condition.

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Background

- The "Sense of Agency (SoA)" is the experience of controlling one's own motor acts (Haggard, 2017). We feel our will drives our body, but it is an illusion. Why our brain creates such illusion? Does SoA alter our action?
- Intentional Binding (IB) is extensively used as a proxy measure of SoA (Haggard, 2017).
- It is reported that under Fear or Anger state, IB effect is lost or decreased (Christensen et. al, 2019).
- There are gambling games in which betting conditions are statistically identical but behavioral outcomes are different (Onzo 2007). The games are supposed to give a different subjective experience of SoA.
- We examined whether the difference of the behavioral outcomes of such gamble game are caused by SoA using IB.

Methods

Libet's clock experiment

The time of when the subject want to push a key was measured by Libet's clock experiment.

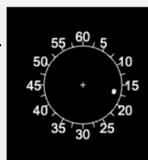
A white dot rotates on clock face within 2560 ms.

The dot starts and ends at random positions.

Tone: 1000Hz, duration: 100ms

Subject #: 14 (Female 7, Age 21-55, Online 11)

20 trials per one condition.

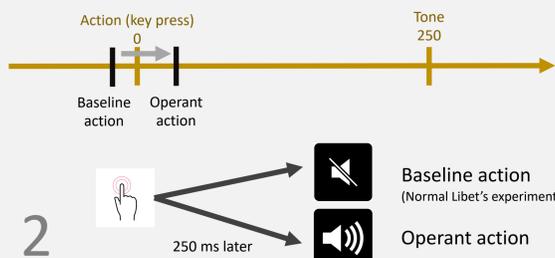


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Intentional Binding

If Libet's clock experiment is conducted with tone following (250ms later), the perceived time of action attracted to tone. This is called intentional binding effect (Haggard et al., 2002).

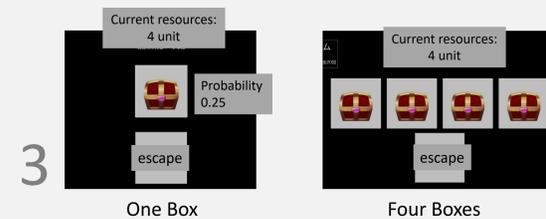
In our experiment, Libet's clock experiment with tone following is called "Operant action", and without tone called "Baseline action".



Methods

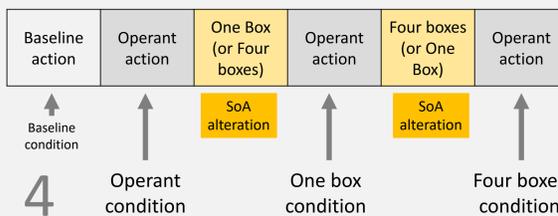
Flat reward condition (Gamble games)

- Two types of gamble game, "One Box" and "Four Boxes", were conducted. They have an identical statistical feature but give different behavioral outcome.
- Subjects have 4-unit-resource at first time. Subjects can choose to bet or escape. One resource must be paid to bet.
- 4 resources are given when it wins. Win rate is ¼ (0.25) and expectation value is 0 in both of one box and four boxes.
- These games were conducted to shift SoA in subjects' mind.
- We conjectured that one box condition gives less agency to subjects than four boxes.
- Initial resources: 4 unit
- 20 trials maximum per game, 2 games
- When a subject lose all resources, then the game ends.



Protocol

The order of "One Box" and "Four Box" was counter-balanced.



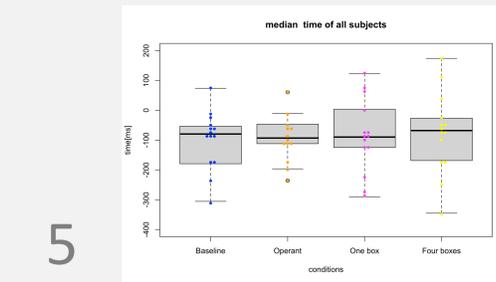
Subjects can participate in this experiment online or onsite. The program of this experiment was written in JavaScript/CSS/HTML.

Conclusion

- Intentional binding effect was not replicated.
- Bet rate of Four boxes was significantly higher.
- SoA may make subjects inhibit futile action.

Results & Discussion

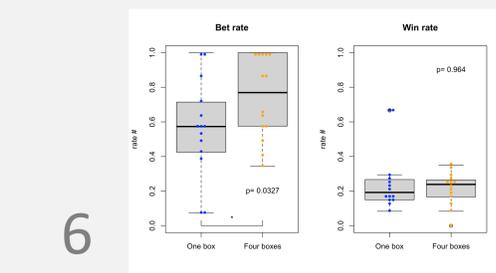
Intentional binding effect was not replicated.



One-way Analysis of Variance (Repeated Measurement) no significance, $F=0.523$, $p=0.668$

- Operant, one box and four boxes conditions should have shown later mean time than baseline condition.
- But there were no difference among four conditions.
- In some subjects, IB effect was found but some showed no IB and the others showed inverse IB effect (i.e. earlier than baseline time).
- Most (11 out of 14) of subjects participated in this experiment online. IB was found in a previous study in which the experiment was conducted online (Galang et al., 2021).

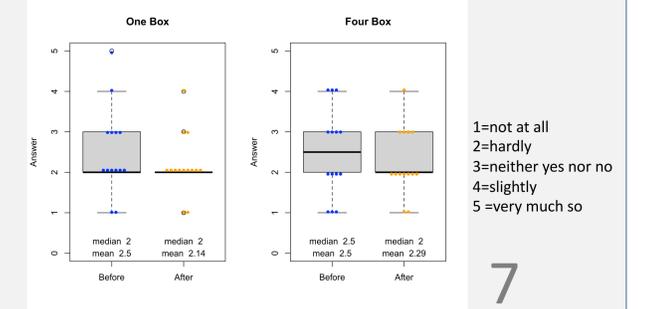
Bet rate of Four box condition was significantly higher than one box.



Bet rate and Win rate

- The higher bet rate is consistent to the previous study (Onzo 2007)
- Subjects liked to bet in four boxes condition although objective probability of winning is the same.
- The actual win rate was about 0.2 in both one box and four boxes condition, within the expected range of variability around the original 0.25 setting.

The difference of Agency was faint. Results & Discussion

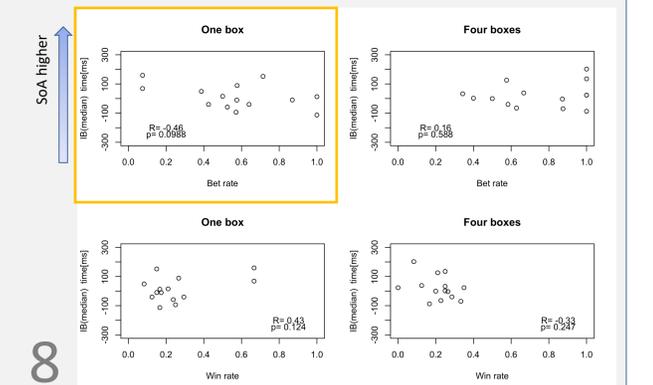


- Before and after each gamble game, the subjects were asked that "How much do you feel that you can tell the win box?" This is a question for measuring SoA.

- In the previous study (Onzo 2007), A higher degree of agency was reported in four boxes than in one box. In our experiment, the number of game repetition was only twice, compared to 30 times in the previous study. That may cause such slight difference in our result (not significant, $p=0.6875$).

- As IB was not replicated, it's not clear whether the gamble games influence the feeling of Sense of Agency or not.

Bet rate of One box indicated negative correlation to IB time. SoA may make subjects inhibit futile action.



- IB (median) time was calculated as below:

$$IB \text{ time [ms]} = W_{of} - B$$

W_{of} : median want time of one box (W_o) and four boxes (W_f)
 B : median want time of baseline

- In one box condition, bet rate and IB seems to have a weak tendency of a negative correlation ($R=-0.46$, $P=0.0988<0.1$). One box and win rate has no significant correlation. Four boxes and bet rate, four boxes and win rate also have no significant correlation.

- In one box condition, the lower the bet rate was, the higher IB was. Considering IB reflecting feeling of SoA, this can be interpreted that when we feel SoA strongly, subjects refrain from futile actions.