The sense of agency can be modulated by the interaction between action optionality and valence of outcomes

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Background

**Sense of agency**
- a feeling of control over one’s actions to cause sensory events in the environment (Moore & Obhi, 2012)

According to previous researches...
1. The more number of action alternatives one has, the more strongly sense of agency he / she feels (Barlas & Obhi, 2013)
2. Negative emotional outcomes attenuate sense of agency (Yoshiie & Haggard, 2013)

→ Does the interaction between action optionality and valence of outcomes modulate sense of agency?

**Method**

- Participants: 25 right handed participants (10 women, mean age = 22.8 ± 1.88)
- Stimuli: 4 each positive and negative non-verbal emotional vocalization stimulus from IADS-2. Each sound was trimmed to 700ms duration.

**Intentional Binding** (Haggard et al., 2002; “IB” from now on)
- Subjective compression of the temporal interval between a voluntary action and its external sensory consequence
- **Implicit** or **immediate** sense of agency

In experimental measurement:
- The difference between baseline (perceived timing of action or stimuli presentation occurring independently) and operant condition (that when action is followed by stimuli presentation). **Action Optionality (two levels)**
  - **Choice:**
    - Choose the one of 7 keys and press
    - **No Choice:**
      - Press the middle one of 7 keys only through the brock

**Valence / Arousal of Outcomes**
- Score ranging from 1 to 9 for each sound rated by each participant after the IB task
- **A.I.B.** task consists of 3 baseline & 4 operant brocks.
  - *Action optionality was consistent through brocks.*
  - *In randomized order, each of 8 sounds was presented 4 times within a brock.

<table>
<thead>
<tr>
<th>Exp. Block</th>
<th>Action (Key press)</th>
<th>Outcome (Sound)</th>
<th>Estimation Event</th>
<th>Number of trials</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Choice</td>
<td>Present</td>
<td>Action</td>
<td>32±2</td>
</tr>
<tr>
<td>B</td>
<td>Choice</td>
<td>Present</td>
<td>Outcome</td>
<td>32±2</td>
</tr>
<tr>
<td>C</td>
<td>Choice</td>
<td>--</td>
<td>Action</td>
<td>32</td>
</tr>
<tr>
<td>D</td>
<td>No choice</td>
<td>Present</td>
<td>Action</td>
<td>32±2</td>
</tr>
<tr>
<td>E</td>
<td>No choice</td>
<td>Present</td>
<td>Outcome</td>
<td>32±2</td>
</tr>
<tr>
<td>F</td>
<td>No choice</td>
<td>--</td>
<td>Action</td>
<td>32</td>
</tr>
<tr>
<td>G</td>
<td>--</td>
<td>Present</td>
<td>Outcome</td>
<td>32±2</td>
</tr>
</tbody>
</table>

* Brock C - F = Action baseline, Brock G = Outcome baseline

**Analysis** by Linear Mixed Model with ML - **Action shift / Outcome shift / Overall binding**

**Explanatory variable:** rating score of Valence and Arousal (as covariance) for each sound by each participant / Action optionality (dummy variable)

**Response variable:** Binding effect (ms)

**Random effect:** (1|subject|+1|subject:Valence|+1|subject:Arousal|+1|subject:Choice)

- Arousal was eliminated from models of overall binding and action shift because of no contribution to fitness (tested with likelihood ratio test).

**[Overall binding]**

There was a significant interaction effect of Valence and Choice.

The result of simple slope test showed:
- Valence of outcomes modulated binding effect only when action was chosen by participants.
- Binding effect in free choice condition was higher than no choice condition when outcomes were more positive.

**Conclusion**

- We found the interaction effect between action optionality and valence of outcomes on intentional binding.
  - Negative emotional outcome *increased* binding effect only when it was caused by an action chosen by oneself.
  - Man more strongly feels sense of agency on negative outcomes caused by their choice (→ a link to responsibility ?)
  - Those results are also the first evidence of interaction of prospective and retrospective cues of sense of agency.
- The interaction effect was found only in “outcome shift” but not in “action shift”.
- There is a possibility the two sides of binding effects have different mechanisms, specifically in terms of the information integration.

**[Action shift]**

There was a significant main effect of Valence.

More positive outcomes induced larger action shifts.

<table>
<thead>
<tr>
<th>Estimate (SE)</th>
<th>df</th>
<th>t value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>16.17 (7.77)</td>
<td>4.23</td>
<td>0.05</td>
</tr>
<tr>
<td>Valence</td>
<td>2.64 (3.12)</td>
<td>218</td>
<td>0.98</td>
</tr>
<tr>
<td>Choice</td>
<td>11.40 (9.91)</td>
<td>24</td>
<td>0.12</td>
</tr>
<tr>
<td>Valence:Choice</td>
<td>-1.52 (1.26)</td>
<td>260</td>
<td>0.65</td>
</tr>
</tbody>
</table>

**[Outcome shift]**

There were significant main effect of Arousal and interaction effect of Valence and Choice.

Simple slope test showed a similar result to that in overall binding.

<table>
<thead>
<tr>
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<th>t value</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>118.45 (14.93)</td>
<td>23.94</td>
<td>0.01</td>
</tr>
<tr>
<td>Valence</td>
<td>-1.56 (1.40)</td>
<td>61.80</td>
<td>0.12</td>
</tr>
<tr>
<td>Choice</td>
<td>13.90 (13.45)</td>
<td>23.98</td>
<td>0.03</td>
</tr>
<tr>
<td>Arousal</td>
<td>-4.15 (2.08)</td>
<td>92.45</td>
<td>0.00</td>
</tr>
<tr>
<td>Valence:Choice</td>
<td>-6.22 (2.23)</td>
<td>204.90</td>
<td>2.72</td>
</tr>
</tbody>
</table>

Rating for sounds

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