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Disentangling the sense of agency and the sense of ownership in the virtual hand illusion paradigm

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Abstract:

We used the virtual hand illusion paradigm to study the relationship between two aspects of the minimal self: the sense of agency and the sense of (body) ownership. Converging evidence for the at least partial independence of agency and ownership was found. For instance, sense of agency was a better predictor of individual anxiety levels than sense of ownership and males showed stronger effects related to agency --- presumably due to gender-specific attribution styles and empathy skills. Taken together, our findings suggest that the sense of agency and the sense of ownership are driven by different kinds of information and related to different psychological functions.

Keywords: sense of agency, sense of ownership, virtual hand illusion, anxiety, contribution style, empathy ability
1 Introduction

The rubber hand illusion is the experience of an artificial body part as being one of the real body parts. This illusion was first reported by Botvinick and Cohen (Botvinick and Cohen, 1998) in which a rubber hand was placed in front of the participants while their own hand was hidden from sight. As long as there were synchronous touches existed on both rubber hand and real hand, a perceptual illusion would be felt. Besides recognizing the fake model hand as being part of their own body, participants also reported that they felt as if the touch they sensed originated from the location on the rubber hand where they see the brush touching the rubber hand, rather than from their real hand (Makin, et al., 2008).

This method is widely used with only minor alternations to induce illusions and investigate individual’s self-perception of the body which is critically important for conscious experience of the self (Folegatti, et al., 2012, Germine, et al., 2013, Jenkinson, et al., 2013, Ocklenburg, et al., 2012). Sense of agency and sense of ownership are considered to be two main aspects of minimal self which according to Gallagher is a basic, immediate, or primitive ‘something’ that we are willing to call a self (Gallagher, 2000a) and thus enables us to capture the most primitive sense of self (Gallese and Sinigaglia, 2010). Therefore, it has attracted considerable empirical and theoretical interest using rubber hand illusion paradigm to study the distinction between sense of agency and sense of ownership in order to explain how we perceive ourselves.

Sense of agency refers to the pre-reflective experience or sense that I am the cause or author of the movement, while sense of ownership is the pre-reflective experience or sense that I am the subject of the movement, that I am experiencing a certain sensation (Tsakiris, et al., 2007). In normal experience of voluntary or willed action, sense of agency and sense of ownership coincide and are indistinguishable, in the case of involuntary movement, however, it is quite possible to distinguish between sense of agency and sense of ownership (Gallagher, 2000b). The distinction between sense of agency and sense of ownership has attracted considerable interests in various fields including psychology, philosophy and cognitive science (Blakemore, et al., 2002, Marcel, 2003, Tsakiris and Haggard, 2005). Although different methodology we may find in different disciplines, there is a growing consensus on this division between sense of agency and sense of ownership. According to experimental research on normal subjects, sense of agency for action based on that which precedes action and translates intention into action while sense of ownership for motor action can be explained in terms of ecological self-awareness built into movement and perception (Gallagher, 2000a).

Haggard, by considering the logic of involuntary movement where there is a sense of ownership but no sense of agency suggested that in ordinary voluntary movement the sense of ownership is generated by sensory feedback, while the sense of agency is generated by or at least linked to the motor commands sent to the muscles and the accompanying efferent copy that is internally processed within the predictive models of the motor system (Haggard, 2005, Tsakiris, Schuetz-Bosbach and Gallagher, 2007).

However, studies focused on the relationship between sense of agency and sense of ownership did not fully address the issues well. There are some controversial results from previous studies. Santo and Yasuda, by manipulating the discrepancy between the intended and actual consequences of actions, found that a discrepancy between...
predicted and actual feedback had significant impacts on sense of agency but no effects on sense of ownership, thus suggested that both senses of self are mutually independent (Sato and Yasuda, 2005) which may not satisfy those who think sense of agency and sense of ownership are at least partially related. Tsakiris and colleagues, using a video-screen-based setup, discovered that the types of proprioceptive drifts differed among different situations. They found localized proprioceptive drifts for tactile and passive stimulation but not for active movement, which means a purely proprioceptive sense of ownership is local and fragmented but the motor sense of agency integrated distinct body parts into a coherent, unified awareness of the body. Their findings not only implied that sense of agency and sense of ownership may involve two mechanisms but also suggested sense of agency modulate sense of ownership during active movement (Tsakiris, et al., 2006). Kalckert and Ehrsson, using a moving rubber hand setup, varied the relative timing of the figure movements, the mode of movement and the position of the model hand. The results that asynchrony eliminated both agency and ownership, passive movements abolished the sense of agency about not the ownership while incongruent positioning the model hand diminished ownership but not agency provided evidence for a double dissociation of sense of agency and sense of ownership, suggesting they may represent distinct cognitive processes. But, due to the observation that stronger agency was experienced when the model hand was perceived to be a part of one’s body, they thought that ownership modulated agency which is just the opposite as what Tsakiris et al., suggested (Kalckert and Ehrsson, 2012).

In the present study, we tried to study the relationship between two aspects of the minimal self from a different perspective by using another illusion paradigm, virtual hand illusion which is another way to induce body perception illusion besides rubber hand illusion and its revised version. In the experiment of virtual hand illusion, participants sit in front of a screen where visual 3D image of the virtual hand would be presented while having tactile stimulation on their real hidden hand. It is indicated that the way of inducing virtual hand illusion can achieve the same effect as what rubber hand illusion did. In other words, imposing the same tactile stimulation on both the virtual hand on the screen and the real hand which is hidden from view can let the participants feel the similar experience to that under rubber hand illusion condition (Ma and Hommel, 2013). Experiment showed that by simply manipulating the temporal delay between participants’ real movement and the movement of the virtual hand on the screen, a virtual hand illusion can be induced even in the absence of tactile stimulation (Sanchez-Vives, et al., 2010). Slater et al., found that there were reliable correlations between the impression of hand ownership and hand-related EMG activation, suggesting a connection between perceived ownership and action control (Slater, et al., 2008). Compared with rubber hand illusion, virtual hand illusion has the following three major advantages. First, for virtual material, in virtual hand illusion we can have more vivid virtual images of participants’ hand while in rubber hand illusion the shape or size of the fake hand are relatively limited. Secondly, for operation, in virtual hand illusion it is very easy to guarantee the synchronicity between virtual and real hand while in rubber hand illusion manual process can’t make sure that the brushing on rubber hand is completely synchronizing with that on real hand. Last but not least, for stimulus material, in virtual hand illusion we can use more novel stimuli such as hit the virtual hand with a ball or a knife while in rubber hand illusion it seems brushing is the only suitable stimulus.
There are already some studies using this paradigm of virtual hand illusion to investigate the relationship between sense of ownership and the affective resonance in facing with different kind of emotional events. Yuan and Steed designed an experiment to measured SCR responses to what they considered threats to a virtual hand and found similar elevations as with rubber hands. Participants were asked to play games in virtual environment by operating the hand of an avatar. During the game a virtual lamp would fall on the virtual hand operated by the participants at some point, which induced a reliable increase in SCR. They placed the hand with an arrow as the control condition which produced significantly less increase in SCR. Taken together, they suggested that people emotionally “care” about what they perceive as being a part of their body but not, or not so much, about what they perceive as belonging to the body of someone else (Yuan and Steed, 2010). However, Ma and Hommel thought that two aspects of Yuan and Steed’s study might help explaining this seeming discrepancy. For one, they did not use the standard synchronization technique to induce different degrees of body ownership. For another, the threatening event merely consisted of a virtual lamp falling on the virtual hand. Even though the contact between the lamp and the hand was clearly visible to the participant, it is difficult to judge from the visual display how much pain. Ma and Hommel adopted the standard synchronization technique to induce the illusion of ownership and replaced the falling of a virtual with a knife. Their findings suggest that ownership was stronger if the virtual hand moved synchronously with the participant’s own hand, but his effect was independent from whether the hand was impacted or threatened. In other words, in the face of threat, affective resonance was independent of synchronicity (Ma and Hommel, 2013).

However, we think there are still some problems that need to be dealt with. It is necessary to make a distinction between sense of ownership and sense of agency. As we have mentioned above they are two major aspects of sense of self closely related but are different from one another. Although sense of agency is tightly integrated with sense of ownership, they are two different kinds of conceptions. Therefore, it is necessary to disentangling the sense of agency and the sense of ownership because they may be driven by different kinds of information and related to different psychological functions.

We think what the synchronicity of stimulus induces is sense of agency rather than sense ownership while the shape of virtual image can affect the sense of ownership. The aim of the present study is to investigate 1) whether varying the time gap between real hand and virtual hand movements (synchronous versus asynchronous), the shape of virtual image (human hand versus cat claw) can induce different degrees of sense of agency and sense of ownership; 2) whether different situations of agency and ownership will affect participants’ anxiety after performing rewarding/punishing task, namely how sense of agency and ownership will influence people’s experience when facing different emotional events.

2 Experiment 1

2.1 Method

2.1.1 Participants
The participants were 64 undergraduate students (32 female, 32 male) from two universities in Zhejiang, China, who were unfamiliar with rubber/virtual hand illusion and took part in this study voluntarily. The age of the participants ranged between 17.92 and 29.96 (M = 20.83, SD = 2.61). All the participants were right handed with normal naked or corrected visual acuity. Ethical approval for this study was obtained from the Zhejiang university ethics committee (RZYJ201409), and informed written consent was obtained from all subjects.

2.1.2 Stimuli and Materials

Experimental Setup.

The study was performed in a virtual environment, which was programmed by VB.NET. A virtual human hand or cat claw was presented on the screen moving either strictly in accordance with the movement of the mouse of slightly delayed (350ms to 500ms). Participants were asked to observe the movement of the virtual human hand/cat claw while moving the mouse with their right hands for 3 minutes. After that, they needed to fill out a 7-item questionnaire which was adopted to evaluate the extent of their virtual hand illusion experience.

Questionnaire.

Based on the 12-statement questionnaire that Kalckert and Ehrsson used to assess the feelings of agency and ownership and their control statements (Kalckert and Ehrsson, 2014a), we readapted the questionnaire according to our design, and the final statements used in our study were as follows (see Appendix 1):

Q1-Q3 are related to the experience of perceiving the hand as the “own” hand, Q4-Q6 are three control statements for the ownership statements, Q7-Q9 are related to the experience of voluntary control, Q10-Q12 are three control statements for the agency statements. However, during the experiment, the order of these statements were randomized in order to avoid participants’ guess and get more objective data.

2.1.3 Procedure

It was a 2-factor between-subjects design. The two factors were synchronicity (synchronous versus asynchronous) and modality (human hand versus cat claw). The purpose of this experiment was to see whether by varying the time gap between real hand and virtual hand movements and the shape of virtual image can induce different degrees of sense of agency and sense of ownership or not.

Participants were seated in front of a computer screen, and they could move the mouse with their right hand after the activation of the program. Each participant was either involved in each of the following situations: synchronous human hand, asynchronous human hand, synchronous cat claw, asynchronous cat claw. In synchronous cases, the movement of the virtual hand on the screen was exactly the same as that of the participant while in asynchronous cases, virtual image’s movements were delayed from the participant’s actual movements by at least 350ms to utmost 500ms. This delayed time was set according to previous study which indicated that a temporal discrepancy of
less than 300ms between visual and tactile stimulation is crucial for the occurrence of the perceptual illusion (Shimada, et al., 2009). The order of the two synchronicity conditions as well as the order of the modality of virtual image were balanced across participants. Participants were asked to manipulate the mouse by moving their hands for 3 minutes, and they were told it was a task which was tend to test the sensitivity of the computer. After the completion of this section, participants were asked to finish a questionnaire with 12 items by choosing a score in a 7 point (-3-3) Likert scale, ranging from -3 for “totally disagree” to 3 for “totally agree”.

2.2 Results

2.2.1 Questionnaire Results for Synchronous versus Asynchronous Movements

When virtual image moved synchronously with participants’ real hand, the mean rating for ownership was -0.70 (SD = 1.86), for ownership control was -1.65 (SD = 1.37), for agency was 2.46 (SD = 0.71), and for agency control was -2.32 (SD = 0.87). By contrast, when there was a delay between the movements of virtual image and participants’ real hand, the mean rating for ownership was -0.75 (SD = 1.58), for ownership control was -1.24 (SD = 1.47), for agency was 0.77 (SD = 1.39), and for agency control was -1.38 (SD = 1.09). A significant main effects of synchronicity on the mean score of sense of agency (F (1, 63) = 37.26, p < 0.001) and agency control (F (1, 63) = 14.79, p < 0.001) were found, while neither for sense of ownership nor ownership control, there was no significant differences on questionnaire scores (see Figure 1). This indicated that synchronicity was critical for the arousal of sense of agency.

2.2.2 Questionnaire Results for Human Hand versus Cat Claw Modality

When the virtual image was human hand, the mean rating for ownership was 0.57 (SD = 1.21), for ownership control was -0.73 (SD = 1.33), for agency was 1.76 (SD = 1.19),
and for agency control was -1.46 (SD = 1.07). When the virtual image was cat claw, the mean rating for ownership was -2.02 (SD = 1.02), for ownership control was -2.16 (SD = 1.14), for agency was 1.47 (SD = 1.57), and for agency control was -2.24 (SD = 0.98).

A significant main effects of modality on ownership (F (1, 63) = 86.01, p < 0.001), ownership control (F (1, 63) = 21.17, p < 0.001) as well as agency control (F (1, 63) = 9.331, p = 0.003) were found, but there was no significant effect of modality on agency, which indicated the influence of modality was only on ownership but not agency (see Figure 2).

![Figure 2 Questionnaire Results for Modality](image)

The questionnaire data clearly indicated that the participants experienced a strong sense of agency over its movements in the synchronous condition, which was significant different from that in the asynchronous condition. However, for sense of ownership, even significant difference between groups was observed, participants’ sense of ownership over the virtual hand was not as strong as we expected (see Figure 3). And it is also much weaker compared with previous studies ([Kalckert and Ehrsson, 2012](http://dx.doi.org/10.7287/peerj.preprints.673v1), [Kalckert and Ehrsson, 2014b](http://dx.doi.org/10.7287/peerj.preprints.673v1)).
2.2.3 Statistical Analysis of Questionnaire Data

We analyzed all the statements by means of a 2 (synchronicity) × 2 (modality) ANOVA. Means and standard deviation (in brackets) for all the statements are listed in Table 1.

Table 1. Experiment 1: Means and Standard Deviation (in brackets) of all the Categories (Ownership, Ownership Control, Agency, Agency Control)

<table>
<thead>
<tr>
<th></th>
<th>Ownership</th>
<th>Ownership Control</th>
<th>Agency</th>
<th>Agency Control</th>
</tr>
</thead>
<tbody>
<tr>
<td>Synchronous</td>
<td>-0.75</td>
<td>-1.24</td>
<td>0.77</td>
<td>-1.38</td>
</tr>
<tr>
<td></td>
<td>(1.58)</td>
<td>(1.47)</td>
<td>(1.39)</td>
<td>(1.09)</td>
</tr>
<tr>
<td>Asynchronous</td>
<td>-0.70</td>
<td>-1.65</td>
<td>2.46</td>
<td>-2.32</td>
</tr>
<tr>
<td></td>
<td>(1.86)</td>
<td>(1.37)</td>
<td>(0.71)</td>
<td>(0.87)</td>
</tr>
<tr>
<td>Human Hand</td>
<td>0.57</td>
<td>-0.73</td>
<td>1.76</td>
<td>-1.46</td>
</tr>
<tr>
<td></td>
<td>(1.21)</td>
<td>(1.33)</td>
<td>(1.19)</td>
<td>(1.07)</td>
</tr>
<tr>
<td>Cat Claw</td>
<td>-2.02</td>
<td>-2.16</td>
<td>1.47</td>
<td>-2.24</td>
</tr>
<tr>
<td></td>
<td>(1.02)</td>
<td>(1.14)</td>
<td>(1.57)</td>
<td>(0.98)</td>
</tr>
<tr>
<td>p (Synchronicity)</td>
<td>0.848</td>
<td>0.195</td>
<td>0.000**</td>
<td>0.000***</td>
</tr>
<tr>
<td>p (Modality)</td>
<td>0.000***</td>
<td>0.000***</td>
<td>0.296</td>
<td>0.001</td>
</tr>
<tr>
<td>p (Interaction)</td>
<td>0.015*</td>
<td>0.525</td>
<td>0.370</td>
<td>0.556</td>
</tr>
</tbody>
</table>

The outcome is clear: we were able to disassociate sense of agency from sense of ownership with our setup. We confirmed what the synchronicity of stimulus induces is sense of agency rather than sense of ownership while the shape of virtual image can affect the sense of ownership. Varying the time gap between real hand and virtual hand movements and the shape of virtual image can induce different degrees of sense of agency and sense of ownership. The lack of interaction significance on ownership
control, agency, and agency control may suggest that sense of ownership and sense of agency are driven by different psychological processes or functions, even in normal experience they are related intimately. Thus we performed the second experiment to examine how sense of agency and sense of ownership could affect anxiety in different situations.

3 Experiment 2

3.1 Method

3.1.1 Participants

The participants were 96 undergraduate students (48 female, 48 male) from two universities in Zhejiang, China, who were unfamiliar with rubber/virtual hand illusion and took part in this study voluntarily. The age of the participants ranged between 17.95 and 29.35 (M = 21.01, SD = 2.53). All the participants were right handed with normal naked or corrected visual acuity. Ethical approval for this study was obtained from the relevant university ethics committee.

3.1.2 Stimuli and Materials

Experimental Setup.

The study was performed in a virtual environment, which was programmed by VB.NET. Experiment 2 composed of two parts. The first part is the same in experiment 1, a virtual human hand or cat claw was presented on the screen moving either strictly in accordance with the movement of the mouse of slightly delayed (350ms to 500ms), and participants were asked to observe the movement of the virtual human hand/cat claw while moving the mouse with their right hands for 3 minutes. Second part appeared right after the end of the first part. In the second part, there were knives or coins falling on the screen, and participants needed to catch coins as well as avoid knives. After finishing the task, participants were asked to complete a State-Anxiety Inventory (S-AI).

Questionnaire.

We adopted S-AI to access participants’ anxiety level after the treatment of experiment (See Appendix 2).

3.1.3 Procedure

It was a 2-factor between-subjects design. The two factors were synchronicity (synchronous or asynchronous) and modality (human hand or cat’s claw). The purpose of this experiment was to study whether different situations of agency and ownership will affect participants’ anxiety after performing rewarding/punishing task or not, namely how sense of agency and ownership will influence people’s experience when facing different emotional events. The procedure was very similar to that in the experiment 1, the movement between the virtual image and participant’s real hand was either synchronous or asynchronous, and the virtual image was either human hand or cat claw, except for participants needed to...
perform a rewarding/punishing task while moving their real hands and watching the movements of the virtual image on the screen after 3-minute’s moving and observing. Participants saw a virtual coin or knife coming down from the top of the screen, and what they needed to do was to catch as many coins as they can or avoiding the cut of the falling knife. There were scores of their performance during the game displayed on the top right corner of the screen. Catching a coin or avoiding a knife would add a point while losing a coin or cutting by a knife would lose a point. There were 12 situations in this experiment. Each participant encountered one. They were asked to play this catching/avoiding game for 3 minutes. At the end of the task, there would be a message printed on the screen which told them the results of their performances. After the experiment, participants needed to fill out the S-AI.

3.3 Results

Considering that anxiety level may not be so sensitive to measure, especially for those statements describing their anxious states, so we only calculated the results of those reverse scoring statements (No. 1, 2, 5, 8, 10, 11, 15, 16, 19, 20) of S-AI. Thus the anxiety score of this study was the sum of scores for question 1, 2, 5, 8, 10, 11, 15, 16, 19 and 20.

3.3.1 Anxiety Results for Synchronous versus Asynchronous Movements

When virtual image moved synchronously with participants’ real hand, the mean anxiety score was 27.52 (SD = 4.43). However, when there was a delay between the movements of virtual image and participants’ real hand, the mean anxiety score was -21.13 (SD = 5.31). A significant main effect of synchronicity on anxiety (F (1, 95) = 41.84, p < 0.001) was found, which indicated that when people felt he/she could control something, then the results of something would affect them more dramatically. An even more interesting thing is for male, this difference is more significant compared with female (See Figure 4). For male, stronger effects related to sense of agency was observed (F (1, 96) = 45.90, p < 0.001), but no significance was found in females. That may because males prefer to do inner attribution which made them feel more anxiety about their performance during the rewarding/punishing task whenever they had a strong sense of agency.
330 Figure 4 Anxiety Results Compared between Synchronicity
331
332 3.2 Anxiety Results for Human Hand versus Cat Claw Modality
333 When the virtual image was human hand, the mean anxiety score was 25.52
334 (SD = 5.66). When the virtual image was cat claw, the mean anxiety score was 23.19
335 (SD = 5.86). A significant main effect of modality on anxiety (F (1, 95) = 3.94, p = 0.05)
336 was also found, but the level of significance was obvious different from that of
337 synchronicity. Moreover, when we looked into the effects of modality on anxiety in terms
338 of sex, there was also difference between males and females. As we have mentioned
339 above, for male, stronger effects related to sense of agency was observed, while for
340 female, stronger effects related to sense of ownership was found, although the
341 difference is not significant (See Figure 5). The possible explanation for this may be the
342 different empathy ability between male and female.
3.3.3 Statistical Analysis of Anxiety Data

We analyzed the anxiety scores by means of a 2 (synchronicity) × 2 (modality) × 2 (sex) ANOVA. A significant main effect of synchronicity (F = (1, 95) = 48.62, p < 0.001) showed that participants had higher average anxiety scores under synchronous conditions than those under asynchronous conditions did. And the significant main effect of modality (F (1, 95) = 6.34, p = 0.014) suggested that different virtual images would lead to participants’ different anxious feelings. The anxious score differed between sex, but did not reach the significant threshold (F (1, 95) = 3.74, p = 0.056). There was also a significant interaction effect between synchronicity and sex, which indicated when involving indifferent sense of agency, men and women reacted differently.

Since the interaction effect of synchronicity, modality and sex is not significant, we ran three other analysis of anxiety scores by means of 2 (synchronicity) × 2 (modality), 2 (synchronicity) × 2 (sex), and 2 (modality) × 2 (sex) respectively. For 2 (synchronicity) × 2 (modality) analysis, the main effects of synchronicity (F (1, 95) = 43.70, p < 0.001) and modality (F = (1, 95) = 5.70, p = 0.019) on anxiety are significant, but no interaction effect was found (See Figure 6a). For 2 (synchronicity) × 2 (sex) analysis, significant effects of synchronicity (F (1, 95) = 45.90, p < 0.001) was found as well as the interaction effect (F (1, 95) = 7.58, p = 0.07) (See Figure 6b). And for 2 (modality) × 2 (sex) analysis, a significant effect of modality on anxiety (F (1, 95) = 4.01, p = 0.048) was found (See Figure 6c).

4 General Discussion

As two major components of minimal self, sense of agency and sense of ownership have attracted more and more study interests. These basic aspects of an individual’s self-perception of the body are critically important for self-consciousness, subjective embodiment, and self-other discrimination. Besides that, they may even affect how we perceive the outside world or how we feel about or react to different emotional events.
In the present study we investigated how the status of sense of agency and sense of
ownership can have impacts on anxious feelings. We performed two experiments to do
the research. Experiment 1 was aim to demonstrate that by varying the time gap
between real hand and virtual hand movements (synchronous versus asynchronous),
the shape of virtual image (human hand versus cat claw) can induce different degrees of
sense of agency and sense of ownership. The second experiment was designed to
reveal how different situations of agency and ownership will affect participants’ anxiety
after performing rewarding/punishing task, namely how sense of agency and ownership
will influence people’s experience when facing different emotional events.

The results of our first experiment showed that we can dissociate sense of agency from
sense of ownership, and the synchronicity affected participants’ sense of agency while
the modality influenced their sense of ownership. However, we did not collect enough
evidence to prove whether sense of agency modulated sense of ownership or vice
versa. Instead, the lack of interaction significance on those categories of sense of self
may suggest that sense of agency and sense of ownership are driven by different
psychological processes or functions.

Our second experiment showed that in general, synchronous conditions had higher
anxiety scores than asynchronous one, no matter for male or female, and has nothing to
do with the modality of virtual image, which indicated that sense of agency may bring us
more sense of responsibility to connect the stress of performing well with anxiety level.
By contrast, the absence of sense of agency can lead people to attribute their bad
performance in rewarding/punishing task to the computer which they cannot control,
which in turn reduce the anxiety in asynchronous conditions. Besides, we found
synchronicity had more impacts on people’s anxiety level than modality did. In other
words, sense of agency played more important role in emotional mediation than sense
of ownership did, even the latter was also crucial to anxiety level according to our study.

However, things were a little bit different when we considered the sex factor. Sense of
agency seemed to affect male more than female while sense of ownership placed more
influence on female than on male. To be specific, men showed more differences
between synchronous and asynchronous conditions than women did, and women
showed more differences between human hand and cat claw conditions than men did.
This finding may because the different contribution styles and empathy abilities between
men and women.

Viewing a human hand was easier to arouse participants’ anxious feelings than facing a
cat claw. That may because of the affection of sense of ownership on emotional feelings.
Even for a virtual image, a body part that was similar with our own body could make us
have more empathy than others, such as a cat claw. That is why we are more likely to
have sympathy for our friend generation. As far as we can tell, women are more sensible
than men, so they should felt more anxious than men. However, in our present study, the
anxiety scores were affected by people’s sense of agency and sense of ownership,
which determined that participants’ attribution styles were also crucial. Because women
are more likely to do external attribution while men prefer internal attribution (Rim, 1990,
Wang, et al., 2013), when dealing with the emotional feelings aroused by the
rewarding/punishing task, the attribution style of female helped them to ease.

5 Conclusion
Based on the paradigm of rubber/virtual hand illusion, we could induce different levels of sense of agency and sense of ownership by manipulating the synchronicity and modality in a virtual environment, which meant sense of agency and sense of ownership were at least partially independent. The status of sense of agency and sense of ownership could further affect participants’ anxiety when they were dealing with stress situations. Sense of agency was a better predictor of individual anxiety levels than sense of ownership, and males seemed to be more sensitive to the effects of sense of agency while females tended to be affected by sense of ownership more compared with males. Taken together, our findings suggest that the sense of agency and the sense of ownership are driven by different kinds of information and related to different psychological functions.
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### Appendix 1: Statements used in Experiment 1 to measure the experience of agency and ownership during different situations.

<table>
<thead>
<tr>
<th>Category</th>
<th>Statement</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agency</td>
<td>I felt as if I could cause movements of the virtual hand.</td>
</tr>
<tr>
<td></td>
<td>I felt as if I could control movements of the virtual hand.</td>
</tr>
<tr>
<td></td>
<td>The virtual hand was obeying my will and I can make it move just like I want it.</td>
</tr>
<tr>
<td>Agency Control</td>
<td>I felt as if the virtual hand was controlling my will.</td>
</tr>
<tr>
<td></td>
<td>It seemed as if the virtual hand had a will of its own.</td>
</tr>
<tr>
<td></td>
<td>I felt as if the virtual hand was controlling me.</td>
</tr>
<tr>
<td>Ownership</td>
<td>I felt as if I was looking at my own hand.</td>
</tr>
<tr>
<td></td>
<td>I felt as if the virtual hand was part of my body.</td>
</tr>
<tr>
<td></td>
<td>I felt as if the virtual hand was my hand.</td>
</tr>
<tr>
<td>Ownership Control</td>
<td>It seems as if I had more than one right hand.</td>
</tr>
<tr>
<td></td>
<td>It felt as if I had no longer a right hand, as if my right hand had disappeared.</td>
</tr>
<tr>
<td></td>
<td>I felt as if my real hand was turning virtual.</td>
</tr>
</tbody>
</table>

### Appendix 2: Questions from State-Anxiety Inventory

<table>
<thead>
<tr>
<th></th>
<th>I feel calm.</th>
<th>11</th>
<th>I feel self-confident.</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>I feel safe, secure.</td>
<td>12</td>
<td>I feel nervous, irritable.</td>
</tr>
<tr>
<td>3</td>
<td>I feel tense, nervous.</td>
<td>13</td>
<td>I feel scared, alarmed, afraid.</td>
</tr>
<tr>
<td>4</td>
<td>I feel stressed.</td>
<td>14</td>
<td>I feel uncertain.</td>
</tr>
<tr>
<td>5</td>
<td>I feel peaceful, good about myself.</td>
<td>15</td>
<td>I am relaxed, at ease.</td>
</tr>
<tr>
<td>6</td>
<td>I feel upset, overwhelmed.</td>
<td>16</td>
<td>I am satisfied.</td>
</tr>
<tr>
<td>7</td>
<td>I worry over possible misfortunes.</td>
<td>17</td>
<td>I am anxious, worried.</td>
</tr>
<tr>
<td>8</td>
<td>I feel happy.</td>
<td>18</td>
<td>I feel disconcerted, disoriented.</td>
</tr>
<tr>
<td>9</td>
<td>I feel frightened.</td>
<td>19</td>
<td>I feel collected, composed.</td>
</tr>
<tr>
<td>10</td>
<td>I feel at ease.</td>
<td>20</td>
<td>I feel pleasant, in a good mood.</td>
</tr>
</tbody>
</table>