

Supplementary Materials

Material evaluation

Methods

Participants

Two separate groups of volunteers (12 (four males) each, mean age 22 years and 20 years respectively) from the University of Birmingham research participation scheme participated in the material evaluation. The first group participated in Part 1 of material evaluation, in which they evaluated the stimuli used in Experiment 1, 2 and 4, on (a) the familiarity of action relation within each object pair, (b) the effectiveness of manipulation of implied actions by changing co-location and (c) affordance of each object (whether an object afford a left or a right hand action). The second group participated in Part 2 of material evaluation, in which they evaluated the distinction between active and passive objects in each object pair. All participants were right-handed and had normal or corrected-to-normal vision. Participants gave informed consent and received monetary compensation for their time.

Materials and Procedure

In Part 1 of material evaluation, greyscale clip-art style images of 29 pairs of objects, including the ten pairs of objects shared by all three experiments, thirteen pairs used only in Experiment 1 and 4 and another six pairs of objects included only in Experiment 2. The evaluation of the 23 object pairs used in Experiment 1 and 4 and the 16 pairs used in Experiment 2 were analysed and reported separately.

Part 1 of the material evaluation task consisted of four blocks. In each block, each object pair was presented in six variations, and each variation was evaluated in one trial, resulting in 174 trials per block. The variations were generated by manipulating orthogonally the object layout (active-left and active-right) and the co-location (correct, incorrect with the active objects manipulated and incorrect with passive objects manipulated). In this way, the material evaluation replicated all the possible displays of the given pair. In each trial, the object pair was presented at exactly the same location and of the same size as they were in Experiment 1, 2 and 4, and the questions were presented below the images. The participants were required to answer the questions on a five-point

scale. The object pair, the question and the choices remained on the screen until a response was made.

In each block, the participants evaluated all object pairs and their variations according to the same question. The sequence of the questions was constant, but the sequence of object pairs within each block varied across blocks and participants.

The four questions served three main purposes:

- a. **Familiarity of the action relation** Regarding whether the objects in each pair are typically involved in certain action relation, and whether the action relations between objects were recognized in the incorrect co-location condition :

Are these objects typically used together?

This question was for block 1.

- b. **Effectiveness of the manipulation of implied action** Regarding whether their co-location is appropriate for an implied action in the correct co-location condition but not in the incorrect co-location condition:

Are these objects appeared to be being currently used together? Or, are they positioned properly or likely to be used together?

This question was for block 2.

- c. **Object affordance** Regarding whether the assumption is valid that objects presented on the left side afford left-hand responses while objects presented on the right side afford right-hand responses:

When the pair of objects are located in the way they are currently located on the screen, and you are going to use them together, which hand are you going to use to handle the object on the right side of the screen?

When the pair of objects are located in the way they are located on the screen, and you are going to use them together, which hand are you going to use if you are going to handle the object on the left side of the screen?

These two questions were for block 3 and 4 respectively.

In Part 2 of material evaluation, the participants evaluated the stimuli regarding the distinction between active and passive objects in each object pair, to validate our assignment of active and passive objects. The objects were presented always in the correct co-location (as if being used

together to fulfilling certain action). Consequently, each object pair was presented only twice, once with the active object on the left and once on the right side of the screen. The question serves the following question:

- d. **Distinction between active and passive objects** regarding which object in each pair was active. The question was presented as:

When the pair of objects are located in the way they are located on the screen, and you are going to use them together, how will these two objects interact? Please press 1 if the object on the left hand side is going to be used upon the right one, and press 2 if the right object is going to be used upon the left one.

Results

The response for materials used in Experiment 1 and 4 and Experiment 2 were analysed and reported separately.

The materials of Experiment 1 and 4

Familiarity of the action relation. Objects in each pair were evaluated as typically involved in interaction, and this perception persisted when the two objects were presented in an incorrect co-location. In response to the question “*Are these objects typically used together?*” on a five-point scale ranging from “*1: definitely No*” to “*5: definitely Yes*”, the mean response to the correctly co-located object pairs was 4.48, $SD = 0.26$; for object pairs in an incorrect co-location, the mean response was 4.45, $SD = 0.26$. One sample t -tests suggest that both ratings significantly diverted from the mid-point, $ps < .001$. A paired sample t -test revealed that the difference between the rating for these two conditions does not differ significantly from each other, $p = .408$.

Effectiveness of the manipulation of implied actions. The manipulation of the implied actions between the stimuli, by changing the co-location, was effective. In response to the question “*Are these objects appeared to be being currently used together? Or, are they positioned properly or likely to be used together?*” on a five-point scale ranging from “*1: definitely No*” to “*5: definitely Yes*”, the mean response to the correctly co-located object pairs was 4.78, $SD = 0.14$; for object pairs in an incorrect co-location, the mean response was 2.23, $SD = 0.82$. One sample t -tests suggests that both ratings significantly diverted from the mid-point, $ps < .001$. The correct co-located object pairs were judged significantly above mid-point, towards the “yes” direction, $p < .001$, while the responses to the

incorrectly co-located object pairs significantly diverted to the "no" direction, $p < .001$. Paired sample t -test revealed that the ratings for these two conditions differed significantly from each other, $p < .001$.

Object affordance. The association between object location and its affordance was evident. The objects presented on the left side afford left-hand responses while objects presented on the right side afford right-hand responses. In response to the question "*When the pair of objects are located in the way they are currently located on the screen, and you are going to use them together, which hand are you going to use to handle the object on the right side of the screen?*" on a five-point scale ranging from "*1: definitely left*" to "*5: definitely right*", the mean response to the correctly presented objects on the right side was 3.32, $SD = 0.53$, the ones on the left 2.88, $SD = 0.72$; for object pairs presented in the incorrect co-location, the mean response to the objects on the right side was 3.28, $SD = 0.52$, for the ones on the left side 2.93, $SD = 0.62$. Though the mean values suggested that participants tend to handle right objects with right hand and left objects left hand, one sample t -tests suggested that none of the ratings significantly differed from the mid-point, $ps > .05$. However, paired sample t -tests revealed significant difference between the rating for left and right objects in both the correct co-location condition ($p = .049$) and the incorrect co-location condition ($p = .034$). Paired sample t -tests showed that co-location did not significantly affect the inclination of handling objects with the hand corresponding to its location on the screen ($ps > .05$).

Active-passive distinction. The active-passive distinction between objects was evident. When the active objects were presented on the left side, the participants tended to report that the left objects were active, while in the other object layout condition the participants tended to report that the right objects were active objects. In response to the question "*When the pair of objects are located in the way they are located on the screen, and you are going to use them together, how will these two objects interact? Please press 1 if the object on the left hand side is going to be used upon the right, and press 2 if the right object is going to be used upon the left one.* ", the mean response when the active objects were on the left side was 1.07, $SD = 0.05$, when the active objects were on the right side 1.98, $SD = 0.04$. One sample t -tests suggested that both ratings significantly differed from the mid-point, $ps < .01$. In addition, paired sample t -tests revealed that the difference between ratings for object pairs of different layouts was significant ($t(11) = -46.30$, $MD = 0.91$, $p < .001$).

The materials of Experiment 2

Familiarity of action relation. Objects in each pair were evaluated as typically involved in interaction, and the perception persisted when the orientation of the passive objects were changed. In response to the question “*Are these objects typically used together?*” on a five-point scale ranging from “1: *definitely No*” to “5: *definitely Yes*”, the mean response to the correctly co-located object pairs was 4.27, $SD = 0.24$; for object pairs presented in an incorrect co-location, the mean response was 4.21, $SD = 0.26$. One sample t -tests suggested that both ratings significantly diverted from the mid-point, $ps < .001$. Paired sample t -tests revealed that the ratings for this two conditions did not differ significantly from each other, $p = .169$.

Effectiveness of the manipulation of implied actions. The manipulation of implied actions by changing the co-location was effective. The appropriateness for immediate interaction existed in the correct co-location condition but not in the incorrect co-location condition. In response to the question “*Are these objects appeared to be being currently used together? Or, are they positioned properly or likely to be used together?*” on a five-point scale ranging from “1: *definitely No*” to “5: *definitely Yes*”, the mean response to the correctly co-located object pairs was 4.67, $SD = 0.16$; for object pairs incorrectly co-located, the mean response was 1.49, $SD = 0.88$. One sample t -test suggested that both ratings significantly diverted from the mid-point, $ps < .001$. The correct co-located object pairs were judged significantly above mid-point towards the “yes” direction, $p < .001$, while the responses to the incorrectly co-located object pairs significantly diverted to the “no” direction, $p < .001$. Paired sample t -tests revealed that the differences between the ratings for these two conditions differed significantly from each other, $p < .001$.

Object affordance. The association between object location and its affordance was evident. The objects presented on the left side afforded left-hand responses while objects presented on the right side afforded right-hand responses. In response to the question “*When the pair of objects are located in the way they are currently located on the screen, and you are going to use them together, which hand are you going to use to handle the object on the right side of the screen?*” on a five-point scale ranging from “1: *definitely left*” to “5: *definitely right*”, the mean response to the correctly co-located objects on the right side of the pairs was 3.43, $SD = 0.49$, the ones on the left side 2.87, $SD = 0.75$; for object pairs incorrectly co-located, the mean response to the objects on the right side was 3.39, $SD = 0.47$, for the ones on the left side the mean response was 2.89, $SD = 0.75$. Though the mean

values suggested that participants tended to handle the right objects with their right hands while the left objects the left hands, one-sample t -tests indicated that none of the ratings significantly diverted from the mid-point, $ps > .05$. However, paired sample t -tests revealed significant difference between the ratings for left and right objects in both correctly co-located ($p = .021$) and incorrectly co-located ($p = .047$) object pairs. Paired sample t -tests suggested that changing the co-location did not significantly affect the inclination of handling objects with the hand corresponding to its location on the screen ($ps > .05$).

Active-passive distinction. The active-passive distinction between objects was evident. When the assigned active objects were presented on the left side, the participants tended to report that the left objects were active, while for pairs with the other layout the participants tended to report that the right objects were the active ones. In response to the question “*When the pair of objects are located in the way they are located on the screen, and you are going to use them together, how will these two objects interact? Please press 1 if the object on the left hand side is going to be used upon the right, and press 2 if the right object is going to be used upon the left one.*”, the mean response when the active objects were on the left side was 1.09, $SD = 0.07$, when the active objects on the right side 1.90, $SD = 0.08$. One sample t -tests suggested that both ratings significantly differed from the mid-point, $ps < .01$. In addition, paired sample t -tests revealed that the difference between ratings for object pairs of different layouts was significant, $t(11) = -20.96$, $MD = 0.81$, $p < .001$.