This manuscript is a preprint of the article

de la Vega, I., Dudschig, C., De Filippis, M., Lachmair, M., & Kaup, B. (2013). Keep your hands crossed: The valence-by-left/right interaction is related to hand, not side, in an incongruent hand – response key assignment. *Acta Psychologica 142*(2), 273-277.

The final version is available here:

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# Keep your hands crossed: The valence-by-left/right interaction is related to hand, not side, in an incongruent hand – response key assignment.

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## Abstract

The body-specificity hypothesis (Casasanto, 2009) associates positive emotional valence and the space surrounding the dominant hand, and negative valence and the space surrounding the non-dominant hand. This effect has not only been found for manual responses, but also for the left and right side. In the present study, we investigated whether this compatibility effect still shows when hand and side carry incongruent information, and whether it is then related to hand or to side. We conducted two experiments which used an incongruent hand – response key assignment, that is, participants had their hands crossed. Participants were instructed to respond with their right vs. left hand (Experiment 1) or with the right vs. left key (Experiment 2). In both experiments, a compatibility effect related to hand emerged, indicating that the association between hand and valence overrides the one between side and valence when hand and side carry contradicting information.

*Keywords*: Embodiment; Body-specificity hypothesis; Handedness; Emotional valence; Crossed hands

Keep your hands crossed: The valence-by-left/right interaction is related to hand, not side, in an incongruent hand – response key assignment.

## 1. Introduction

Right-handers prefer to perform actions with their right hand, whereas left-handers prefer their left hand for manual acts. This statement is far from surprising; however, what might be surprising is that this preference of the dominant hand for concrete actions can even affect the processing of an abstract dimension like emotion. It seems that the preference for one hand leads to an association of positive entities with the dominant hand, or the space surrounding the dominant hand, and to an association of negative entities with the space surrounding the non-dominant hand. This is what Casasanto and colleagues have found in several studies employing non-linguistic stimuli and gestures (Casasanto, 2009; Casasanto & Chrysikou, 2011; Casasanto & Jasmin, 2010). According to Casasanto (2009), the origin of this association can be traced back to the different degrees of fluency attached to the two hands of a person (see Casasanto & Chrysikou, 2011). People are much more fluent with their dominant hand, and because actions performed with this hand are easier, greater fluency is associated with positive affects (see Winkielman et al., 2003). This connection between fluency and positive affect seems to generalize from fluency per se to the side associated with fluency, leading thus to the linkage of side and affect. Such a linkage, modulated by handedness, can be explained by the “body-specificity hypothesis” (Casasanto, 2009), according to which mental representations shaped by interacting with the surrounding world may be different for people with different bodies (see Brookshire & Casasanto, 2012; Willems et al., 2010; Willems et al., 2009).

One prediction from this hypothesis is that different associations between the right or left side and affect should be found for right- and for left-handers. That is, right-handers should associate positive entities with their right hand and negative entities with their left, whereas for left-handers, the reverse is expected to hold true. This idea is consistent with the theory of grounded cognition

(Barsalou, 2008; Zwaan, 2004) and was corroborated in various experiments (Casasanto, 2009; Casasanto & Chrysikou, 2011; Casasanto & Henetz, 2012; Casasanto & Jasmin, 2010).

De la Vega et al. (2012) extended this research to response time (RT) studies employing linguistic stimuli. We found an association between valence and left/right (in the following, valence-by-L/R) in a valence judgment task containing an explicit mapping of valence to one response side. Right-handers preferred to press a key on the side of their right hand to classify positive items, and a key on the side of their left hand side to classify negative items. For left-handers, this pattern was reversed: shorter RTs emerged when they pressed a key on their left to respond to positive items, and a key on their right for negative stimuli.

Previous studies have shown that the association between valence and left/right emerges when no response hand is used (Brunyé et al., 2012; Casasanto, 2009; Casasanto & Chrysikou, 2011; de la Fuente et al., 2011), which indicates that this association generalizes from hand to the whole side of the body. For example, when participants were asked to choose products presented on the right and on the left side, they tended to prefer the product presented on the side of their dominant hand. This preference for the dominant side was also found when participants did not use their hand to respond but indicated verbally whether they would place a positive object on the right vs. the left side (Casasanto, 2009). Such a generalization from hand to side seems plausible as in most of the cases, the right hand and right-hand actions correspond to an individual's right side, and the left hand to the left side. Only seldom do hand and side differ with respect to the spatial information they carry. In our RT studies, for example, participants pressed a key located on their right side with their right hand, and a key located on their left side with their left hand (de la Vega et al., 2012). What happens, however, when hand and side carry contrasting information and participants press a key located on their left with their right hand, and a key on their right with their left hand? Do we still find an association between hand and emotional valence if hand and side are dissociated? And if we do, is this association related to the hand executing the key press, or rather to the location of the response key?

The question whether a given finding is related to intra- or extracorporal space when they carry different information has been investigated already for various associations, such as the link between numbers and space. One of the experiments conducted by Dehaene et al. (1993) to investigate the SNARC effect involved the question whether this association between numbers and space is related to the hand of an individual or to the extracorporal space when participants respond to small and large numbers with their hands crossed. Responses to small numbers were still faster with the left key (and the right hand), and responses to large numbers with the right key (left hand; Dehaene et al., 1993, Exp. 6; but see Wood et al., 2006, for a failure to replicate this finding). The SNARC effect, it seems, depends on a more general representation and not (only) on the hand; thus, it is specific for side and not hand when those are dissociated.

However, there is a crucial difference between different associations between stimulus and space like the aforementioned valence-by-L/R interaction on the one hand, and the SNARC effect (Dehaene et al., 1993) or the mental timeline (Santiago et al., 2007; Weger & Pratt, 2008) on the other hand. The mental timeline refers to the association between temporal expressions and left / right responses. For both the SNARC effect as well as the mental timeline, an influence of the culture to which individuals had been exposed has been shown. There is strong evidence that the direction of the association between small / large numbers and the left / right (SNARC), and between past / future events and the left / right (mental timeline) is modulated by the writing direction of a culture (see Dehaene et al., 1993, and Zebian, 2005, for the SNARC effect; Ouellet et al., 2010, for the mental timeline). While this cultural exposure may shape bodily representations, the origin of these associations lies in the space surrounding individuals. Consequently, it seems only natural that the SNARC effect should not depend on the hand, but on extracorporal space as the incongruent assignment of hand and response keys shows. In this respect, these associations are similar to the Simon effect (Simon, 1969), the finding that responses are faster when stimulus and response occur in the same location (i.e., a left reponse is required for a visual stimulus occurring in the left part of a screen). Although its origin and underlying mechanisms are very different from the SNARC effect, the Simon effect is also based on extracorporal space, and the stimulus is again mapped on response key, not hand, in a crossed-hands setup (Wallace, 1971). In contrast to the SNARC effect and the mental timeline, no cultural influence has been determined for the valence-by-L/R association. Linguistic expressions that link positive entities to the right side, and negative to the left side (e.g., *right* meaning also *correct*) do not seem to have a mental equivalent that influences an individual's associations of valence and space (Casasanto, 2009; see also de la Vega et al., 2012). The important difference between associations influenced by culture such as the SNARC effect and the mental timeline on the one hand, and body-specific associations on the other hand is, thus, that the latter does not depend on cultural influence but on an individual's body (Casasanto, 2009). We can therefore say that this association is intracorporal and might depend on the hand, whereas culture-specific associations are extracorporal and depend therefore on the space surrounding an individual, and not on his or her body. We might therefore expect that, although associations between valence and side are found when only side is relevant for the task at hand (see Casasanto, 2009; Casasanto & Chrysikou, 2011; de la Fuente et al., 2011), in a task in which side and hand carry different information this association is related to hand, not side, as the association seems to arise due to the different degrees of fluency of an individual, and to generalize from hand to side (Casasanto, 2009; Casasanto & Chrysikou, 2011). However, although less likely and in contrast to our assumptions so far, an alternative explanation exists: Theoretically, it might be that the valence-by-L/R associations do not have their origin in an individual's hand, but, in fact, in the space surrounding an individual. It might be that right-handers prefer the space surrounding their right hand and left-handers the space surrounding the left hand due to their different cerebral organization, and that this preference for side generalizes to hand. Exploring the importance of hand vs. side in an incongruent hand – response key assignment might find evidence for such an alternative explanation, or could rule it out.

As mentioned above, it has already been shown that the direction of the valence-by-L/R interaction in response time tasks is modulated by handedness (de la Vega et al., 2012). To keep the focus on the current research question whether the compatibility effect is related to hand or side in an incongruent hand – response key assignment, only right-handers participated in the present experiments. We conducted two RT studies. Both required a valence judgment and contained an explicit stimulus-response mapping. Participants executed key presses with their hands crossed. They pressed a key located on the left with their right hand, and a key located on the right with their left hand.

## 2. Experiment 1

Participants classified positive and negative nouns according to their valence using an incongruent hand – response key assignment. Participants crossed their hands during the experiment, pressing a key located on the right with their left hand, and a key located on the left with their right hand. Participants were told to respond to a positive (negative) word with their right (left) hand, or vice versa. Thus, the instruction mapped positive vs. negative words either on participants' right vs. left hand, not on the right vs. the left response key. We expected three possible outcomes: First, an interaction between valence and hand might show. An alternative outcome would be an interaction between valence and side. A third possibility might be that no interaction shows when hand and side carry incongruent information. Due to the intracorporal origin of the valence-by-L/R association, an interaction related to hand might be the most probable outcome.

### 2.1 Method

#### 2.1.1 Participants

32 right-handers (6 males) participated in the experiment. Mean age of participants was 25.5 years

(*SD* = 5.8). All participants were native German speakers.

### 2.1.2 Materials and Apparatus

Fourty German words (20 positive, 20 negative) were used. Fourty German pseudowords served as fillers. Response was collected with a computer keyboard placed in front of the screen. Participants held their hands crossed. They pressed with their right hand “Q”, located at the left of the keyboard, and with their left hand “9” (on the number pad).

### 2.1.3 Procedure and Design

Half of the participants started by pressing “Q” for positive words and “9” for negative words. In the second part of the experiment, this assignment was reversed. For the other half of participants, this order was the other way around. Participants did not respond to pseudowords. The same set of stimuli was used in both parts of the experiment. The experimental design thus included three factors: response side (left vs. right), valence of stimuli (positive vs. negative), and order of the stimulus – response mapping.

## 2.2 Results and Discussion

Only RTs of correct responses were submitted to the analyses. To take into account not only differences between participants but also between the items, we conducted a two-step procedure to determine outliers (see Dudschig et al., 2012; Kaup et al., 2006). First, we converted RTs of each participant to z-scores. In a second step, we again standardized the values, this time for each item and condition. Z-scores deviating more than 3 SDs from response mean were excluded (< 2% in both experiments).[1]

The remaining RTs were submitted to two 2 (valence: positive vs. negative) × 2 (side of response: left vs. right) × 2 (order of conditions) ANOVAs, one treating participants as random factor ($F_1$) and one items ($F_2$). Due to lacking theoretical relevance, the results of order of conditions will not be reported.

[1] Similar results emerged when no outlier elimination was conducted.

Overall RT was 749 ms (see Table 1 for mean reaction times in the four conditions). A main effect of valence emerged ($F_1(1, 30) = 19.52$, $p < .001$, $\eta_p^2 = .39$; $F_2(1, 38) = 8.55$, $p = .006$, $\eta_p^2 = .18$), with faster responses to positive than to negative words (734 vs. 765 ms). This effect has been observed in previous valence judgment studies employing the same item material (de la Vega et al., 2012). Although responses with the left key (right hand) were numerically faster than with the right key (left hand, 745 vs. 754 ms), there was no main effect of response side ($F_1(1, 30) = 2.39$, $p = .13$, $\eta_p^2 = .07$; $F_2(1, 38) = 2.79$, $p = .10$, $\eta_p^2 = .07$). Crucially, an interaction between valence and space was observed ($F_1(1, 30) = 6.00$, $p = .02$, $\eta_p^2 = .17$; $F_2(1, 38) = 16.80$, $p < .001$, $\eta_p^2 = .31$): Responses were faster with the right hand (and left key) than with the left hand to positive items (719 vs. 748 ms), and with the left hand (and right key) than with the right hand to negative items (760 vs. 770 ms; see Fig. 1). Separate analyses for positive and negative words only showed a main effect for response hand for positive items ($F_1(1, 30) = 7.23$, $p = .01$, $\eta_p^2 = .19$; $F_2(1, 19) = 18.06$, $p < .001$, $\eta_p^2 = .49$), but not for negative items ($F_1(1, 30) = 1.23$, $p = .28$, $\eta_p^2 = .04$; $F_2(1, 19) = 2.73$, $p = .11$, $\eta_p^2 = .13$).

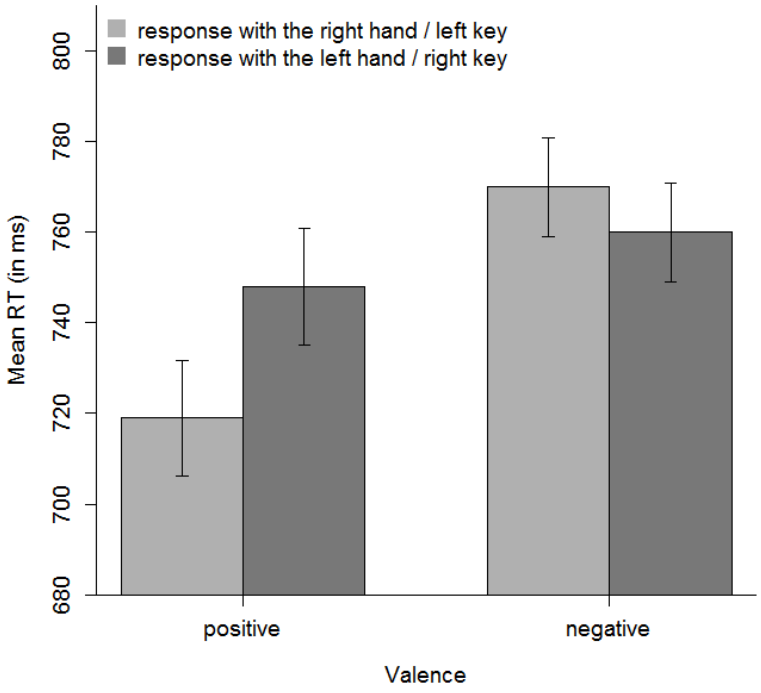
No main effects or valence-by-hand interaction were found in the error analyses (all *F*s < 1), indicating that the main effect of valence and, more important, the valence-by-hand interaction reflected in RTs cannot be explained by speed-accuracy trade-offs.

Table 1

*Mean response times in Experiments 1 and 2*

| | | Response hand | |
|---|---|---|---|
| Experiment | Valence | left | right |
| Experiment 1 | positive | 748 | 719 |
| | negative | 760 | 770 |
| | | | |
| Experiment 2 | positive | 710 | 682 |
| | negative | 727 | 741 |

*Figure 1*. Mean response times in Experiments 1 for responses to positive and negative linguistic stimuli with the right hand / left key or with the left hand / right key. The error bars represent confidence intervals for within-subject designs and were computed as recommended by Masson and Loftus (2003).




An interaction between valence and hand emerged in Experiment 1. Participants responded faster with their dominant hand to positive words and with their non-dominant hand to negative words, although they held their hands crossed during the experiment. This finding shows clearly that hand and side do not have to carry congruent information for an association between emotional valence and left/right responses to show. The fact that in this experiment, the association is related to hand, not side, provides strong evidence for the idea that the valence-by-L/R association has its origin in the fluency of a hand (Casasanto, 2009). The outcome of the study fits nicely with the body-specificity hypothesis, that is, with the idea that individuals with different bodies may think differently according to the experiences they have made with their physical environment (Casasanto, 2009). The different processing of positive and negative entities for people with different bodies, which follows from that hypothesis, led us to expect a modulation of the valence-by-L/R association by hand as the origin for such an association should be clearly intracorporal, not extracorporal. Thus, hand should play a more important role for the valence-by-L/R association than side.

However, the study contains a possible confound. The instruction mapped the stimuli explicitly on participants' hands, not on response keys. One could argue that this was the reason for the outcome of Experiment 1. To rule out this explanation, we conducted Experiment 2, which differed from Experiment 1 in only one aspect, namely the instruction, which mapped responses to stimuli on the left vs. the right response key, not hand.

## 3. Experiment 2

As in Experiment 1, participants performed a valence judgment with their hands crossed. The only difference to Experiment 1 was the instruction: Participants were told to respond to a certain stimulus with the right or left response key, not with their right or left hand.

### 3.1 Method

#### 3.1.1 Participants

32 native German speakers (6 males) took part in the experiment. All participants were right-handed (mean age = 24.1 years, *SD* = 3.6). None of them had participated in Experiment 1.

#### 3.1.2 Materials and Apparatus

The same materials and apparatus as in Experiment 1 were used, with the exception of the instruction. Participants were now instructed to respond to a positive (negative) word with the right (left) response key or vice versa, not with their right or left hand.

#### 3.1.3 Procedure and Design

The procedure and design of the experiment were the same as in Experiment 1.

### 3.2 Results and Discussion

Only RTs of correct responses were submitted to analysis. The same outlier procedure as in Experiment 1 was conducted, reducing the data set by less than 2%.[2] The same data analyses as in Experiment 1 were carried out.

Overall RT was 715 ms (see Table 1 for mean reaction times across the different conditions). As in Experiment 1, a main effect for valence emerged ($F_1(1, 30) = 53.84$, $p < .001$, $\eta_p^2 = .64$; $F_2(1, 38) = 12.44$, $p = .001$, $\eta_p^2 = .25$). Participants responded faster to positive than to negative items (696 vs. 734 ms). No main effect for response hand emerged ($F_1(1, 30) = 1.07$, $p = .31$, $\eta_p^2 = .03$; $F_2(1, 38) = 1.53$, $p = .22$, $\eta_p^2 = .04$). Again, an interaction between valence and space showed ($F_1(1, 30) = 6.07$, $p = .02$, $\eta_p^2 = .17$; $F_2(1, 38) = 26.70$, $p < .001$, $\eta_p^2 = .41$). As in Experiment 1, participants responded faster with their right hand (left key) to positive words than with their left hand (682 vs. 710 ms), and with their left hand (right key) to negative words than with their right hand (727 vs. 741 ms; see Fig. 2). Separate analyses for positive items and negative items yielded a main effect of response hand for positive items both in the by-participants and the by-items analysis ($F_1(1, 30) = 5.83$, $p = .02$, $\eta_p^2 = .16$; $F_2(1, 19) = 16.59$, $p < .001$, $\eta_p^2 = .47$), and a main effect of response hand in the by-items analysis for negative items ($F_1(1, 30) = 1.78$, $p = .19$, $\eta_p^2 = .06$; $F_2(1, 19) = 10.11$, $p = .005$, $\eta_p^2 = .35$).

The error analyses showed a tendency for an effect of hand ($F_1(1, 30) = 3.45$, $p = .07$, $\eta_p^2 = .10$; $F_2(1, 38) = 3.80$, $p = .06$, $\eta_p^2 = .09$). Left-hand responses evoked less errors than right-hand responses (2.4% vs. 3.7%). No effect of valence (both *F*s < 1) emerged. No valence-by-hand interaction was found in the error analyses ($F_1(1, 30) = 2.08$, $p = .16$, $\eta_p^2 = .06$; $F_2(1, 38) = 2.14$, $p = .15$, $\eta_p^2 = .05$).

Experiment 1 and 2 were submitted to a joint analyses, in which Experiment was treated as a between-factor. No influence of Experiment on the valence-by-L/R interaction emerged (both *F*s < 1).

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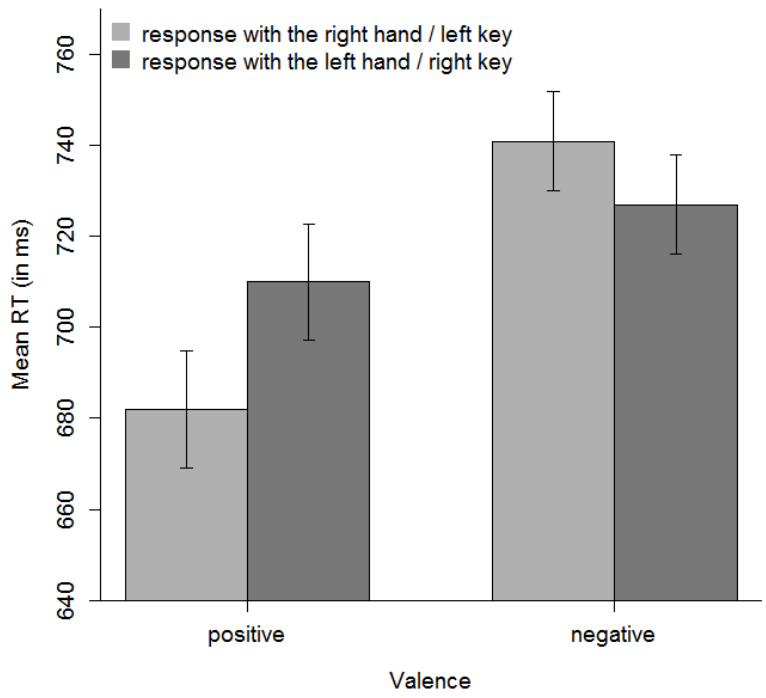
[2] A similar pattern emerged when no outlier elimination was conducted.

*Figure 2.* Mean response times in Experiments 2 for responses to positive and negative linguistic stimuli with the right hand / left key or with the left hand / right key. The error bars represent confidence intervals for within-subject designs and were computed as recommended by Masson and Loftus (2003).




The same pattern as in Experiment 1 emerged in Experiment 2. Participants responded faster with their dominant hand to positive items and with their non-dominant hand to negative items, that is, the valence-by-L/R interaction was related in both experiments to hand, not side. In Experiment 1, we could not exclude that this finding emerged due to the instruction, which mentioned hand, not side. However, exactly the same pattern was found in Experiment 2, in which the instruction had mapped the stimuli to the response keys. It is remarkable that the instruction did not change the results, especially when bearing in mind that instructions can drastically change the outcome of an experiment (see, for example, Eder & Rothermund, 2008). Taken together, the two experiments provide clear evidence for a strong association between valence and hand. When hand and side carry contradicting information, the valence-by-L/R interaction is related to hand, not side, even when the instruction emphasizes the connection between valence and side. In studies were only side is relevant, side alone obviously does have an influence on the processing of emotional information; thus, an interaction between left/right and valence emerges even when no response hand is used (see Casasanto, 2009; Casasanto & Chrysikou, 2011; de la Fuente et al., 2011). However, the present studies indicate that the association between hand and valence overrides the one between side and valence when the left – right information given is incongruent.

**4. General Discussion**

In two experiments, we investigated whether an association between valence and space shows in a response time task with an incongruent hand – response side assignment. Participants held their hands crossed and pressed a key located on the left with their right hand, and a key located on the right with their left hand. The experiments differed merely with respect to the instruction: In Experiment 1, participants were instructed to respond with their right or left hand, whereas in Experiment 2, they were told to respond with the left or right key. A valence-by-L/R interaction related to hand, not side, emerged in both experiments.

The finding that an association still shows when hand and side carry contradicting information and that this association is, furthermore, related to hand, not response side, stands in contrast to previous studies investigating other spatial associations, namely the SNARC effect. Here, the association between space and numbers has been shown to be related to response side, not hand (Dehaene et al., 1993). However, bearing in mind that the association between valence and space has its origin in the body of an individual, namely in the ease with which individuals use their dominant versus their non-dominant hand, it should not be surprising that this association is related to hand when hand and side carry contradicting information. What might come as surprise is that this is not only the case when the instruction directs participants' attention to the association between valence and hand (Experiment 1). The valence-by-L/R association does still follow hand when the instruction maps it to the response keys, that is, to side (Experiment 2). This finding indicates that the connection is stronger between valence and hand than between valence and side. The importance of hand suggests, furthermore, that the fluency of dominant vs. non-dominant hand plays a crucial role for the emergence of the link between valence and space (Casasanto, 2009; Casasanto & Chrysikou, 2011). The results presented here indicate that the valence-by-hand interaction found is mainly due to the presence of fluency associated with positive affect (Reber, Winkielman, & Schwarz, 1998), as post-hoc analyses reveal an effect for positive, but not always for negative stimuli (but see de la Vega et al., 2012, Experiment 2, where a main effect of hand for negative items shows).

However, there exists an alternative explanation for the findings presented here. According to the polarity correspondence principle (Lakens, 2011; Proctor & Cho, 2006), participants in binary classification tasks code binary stimuli and response alternatives as + or -, + being given to the more salient entity of the two. The positive entity as the more salient entity would then receive a +, the negative entity a -. Similarly, the more salient response alternative would receive a +. In the studies reported here, it seems plausible that of the two response alternatives, dominant hand vs. non-dominant hand, the dominant hand should be the more salient response alternative. Thus, the dominant hand (in our case, the right hand) would receive a + and the non-dominant hand (in our case, the left hand) a –. The polarity correspondence principle assumes that stimulus and response alternatives with the same coding are associated and predicts an interaction between stimulus and response alternative driven by the salient stimulus. In fact, Experiment 1 showed exactly the pattern predicted by the polarity correspondence principle: a difference for positive, but not for negative, items with respect to the response hand emerged (see Lakens, 2012, for a similar pattern for more vs. less salient words presented in the upper vs. lower visual field). Such a mapping between the salient features of the stimuli and the salient features of the responses might, furthermore, fit the theory of event coding (Hommel, Müsseler, Aschersleben, & Prinz, 2001). However, the pattern in

Experiment 2 is slightly different from what the polarity correspondence principle would predict: here, we found a difference between responses with the left vs. right hand to negative items in the by-items analysis. While the polarity correspondence principle cannot be applied to most studies investigating the association between valence and left/right, future research is needed to explore this alternative explanation of the reported compatibility effect in response time studies. Differentiating between these two alternatives might prove to be challenging, however, as distinguishing between processing fluency and salience asymmetries is difficult (see Rothermund & Wentura, 2001; 2004; Chang & Mitchell, 2009; 2011).

In conclusion, the two studies presented provide strong evidence for the intracorporal origin of the body-specificity hypothesis. The fact that the valence-by-L/R interaction was, independent of the instruction, related to hand in both experiments corroborates the idea that hand is the relevant factor in the emergence of body-specific associations.

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## Author Note

We thank Daniel Casasanto, Daniël Lakens, and an anonymous reviewer for helpful comments on an earlier version of the manuscript, and Sibylla Wolter, Matthias Hüttner, Jonathan Maier, and

Eduard Berndt for data collection. This work was supported by a research grant from the German Research Foundation (DFG) to Barbara Kaup (SFB 833, project B4).