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ORIGINAL ARTICLE

Coding valence in touchscreen interactions: hand dominance and lateral movement influence valence appraisals of emotional pictures

Sergio Cervera Torres[1,2] · Susana Ruiz Fernández[1,2] · Martin Lachmair[1] · Peter Gerjets[1,2]

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Abstract

The Body-Specificity Hypothesis postulates that the space surrounding the dominant hand is perceived as positive due to the motor fluency of this hand, whereas the space surrounding the non-dominant hand is perceived as negative. Experimental studies based on this theoretical framework also revealed associations between affective valence and hand dominance (i.e., dominant hand—positive; non-dominant hand—negative), or lateral movements of the hands (i.e., right hand toward the right space—positive; left hand toward the left space—positive). Interestingly, these associations have not been examined with regard to how lateral actions of the hands may influence affective experiences as, for example, in valence appraisals of affective objects that have been manipulated. The study presented here has considered this question in light of the emerging interest of embodied cognition approaches to interactive technologies, particularly in affective experiences with touchscreen interfaces. Accordingly, right-handed participants evaluated the valence of positive and negative emotional pictures after interacting with them either with the dominant right or with the non-dominant left hand. Specifically, they moved the pictures either from left to right or from right to left sides of a touchscreen monitor. The results indicated that a valence matching between the hand used for the interactions, the picture's valence category, and the movement's starting side reinforced the valence appraisals of the pictures (i.e., positive/negative pictures were more positively/negatively evaluated). The findings are discussed against the background of the Theory of Event Coding, which accounts for both the affective properties of the stimuli and the affective connotation of the related action.

Introduction

Theories of embodied cognition are concerned with the question of how perception and action in and with our environment may influence cognition and emotion (e.g., Barsalou, 2008; Hommel, 2015; Niedenthal, 2007). Along this line of reasoning, some embodied approaches to emotion suggest that bodily actions may influence affective experiences, as reflected for instance, in valence appraisals towards stimuli. For example, positive stimuli are typically evaluated more positively if subjects exhibit "smiling" facial expressions, whereas negative stimuli are more negatively evaluated if subjects exhibit "frowning" expressions (e.g., Havas, Glenberg, & Rink, 2007; Larsen, Kasimatis, & Frey, 1992; Strack, Martin, & Stepper, 1988. For a complete overview, see also the recent Registered Replication Report by Wagenmakers et al. (2016) which failed to replicate the results of the study by Strack et al.). Conversely, if the facial expression is not congruent with the presented stimulus, its valence evaluation may be lowered (e.g., negative stimulus less negatively evaluated when "smiling"; Söderkvist, Ohlén, & Dimberg, 2017). In other words, when the feedback stemming from a bodily action match the perceived affective valence of a stimulus, its valence evaluation may be reinforced, but also attenuated when the feedback mismatch (Clore & Schnall, 2008; Schwarz, 2001). Interestingly, this theoretical view

✉ Sergio Cervera Torres
s.cervera-torres@iwm-tuebingen.de

Susana Ruiz Fernández
s.ruiz-fernandez@iwm-tuebingen.de

Martin Lachmair
m.lachmair@iwm-tuebingen.de

Peter Gerjets
p.gerjets@iwm-tuebingen.de

1 Leibniz-Institut für Wissensmedien, Schleichstr. 6, 72076 Tübingen, Germany

2 LEAD Graduate School and Research Network, Eberhard Karls University of Tübingen, Tübingen, Germany

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becomes increasingly important when considering novel technological environments (e.g., touchscreens) and how their physical interaction may be related to the recognition, processing or influence of a user's affective experience (e.g., Dourish, 2004; Farr, Price, & Jewitt, 2012; Picard, 2003). In line with this notion, the present study is particularly concerned with the question as to whether or how interactions with the hands in such environments might influence valence appraisals of emotional content. To approach this issue, however, we were first interested in how the affective mechanisms that potentially come into play during such interactions would work.

In this regard, embodiment research has revealed that hand dominance is strongly associated with mental representations of affective valence. For example, the Body-Specificity Hypothesis (BSH; Casasanto, 2009) postulates that right handers associate the space surrounding the dominant right hand (i.e., dominant right space) with a positive valence and the space surrounding the non-dominant left hand (i.e., non-dominant left space) with a negative valence. In contrast, left handers would exhibit the opposite pattern. A series of forced-choice experiments supported these space–valence associations. First, when asked to choose between the right or left space of a sheet of paper, right-handed participants tended to assign positive stimuli (e.g., animal cartoons) to the right space, but negative ones to the left space (see also Casasanto & Henetz, 2012; Freddi, Brouillet, Cretenet, Heurley, & Dru, 2016). Furthermore, these participants also evaluated novel stimuli (e.g., images depicting cartoon creatures) presented in the dominant right space as more positive and novel stimuli presented in the non-dominant left space as more negative. As predicted, left-handed participants showed the reversed pattern in both tasks. As an explanation of these associations, the BSH assumes that actions of the dominant hand are typically more fluent, especially within its space (e.g., the right hand in the right-side space; Carey, Hargreaves, & Goodale, 1996). Related findings suggest in addition that the motor fluency associated with an action is positively marked (e.g., requiring less effort; Beilock & Holt, 2007; Cannon, Hayes, & Tipper, 2010; cf. Winkielman & Cacioppo, 2001; Winkielman, Schwarz, Fazendeiro, & Reber, 2003). For instance, right handers preferred non-affective objects (e.g., kitchen utensils) when directly moving them from positions that facilitated their grip (Ping, Dhillon, & Beilock, 2009). Similarly, right handers evaluated the valence of household objects more positively after directly moving them from the right to the left or the left to the right locations on a table; however, only when the movements were performed without the interference (vs. with interference) of an obstacle (e.g., a vase filled with water; Hayes, Paul, Beuger, & Tipper, 2008). Nevertheless, beyond the perceived affective consequence derived from the motor fluency of an action (e.g., better object grip or absence of an obstacle), such influence of an action on affect has also been linked to the space–valence associations reported in the BSH. Specifically, Milhau, Brouillet, and Brouillet (2013) showed that right handers evaluated neutral words as more positive when presented in the middle center of a monitor screen. This effect appeared after participants moved the dominant right hand from a centered key on a keyboard to a key at the right side (i.e., a fluent lateral movement); yet, the numerical scale subsequently used to evaluate the words after performing this movement was labelled according to a congruent space–valence mapping for right handers (i.e., the scale presented a positive label on the right side and a negative label on the left side). In contrast, the incongruent mapping (i.e., the positive label at the left side and negative label at the right side) did not lead to the same positive effects.

Interestingly, embodiment accounts also suggest that interacting with or perceiving objects may partially reactivate past affective and sensorimotor experiences associated with them (Niedenthal, Winkielman, Mondillon, & Vermeulen, 2009; Wilson, 2002). In line with this notion and consistent with the BSH theoretical framework, some studies report that processing valence-laden concepts (e.g., words) may facilitate not only perceptual judgments related to the non-/dominant space (Milhau, Brouillet, Dru, Coello, & Brouillet, 2017), but also compatible motor responses of the dominant or non-dominant hand. To put this concretely, when positive words were presented in the middle center of a computer screen, right handers judged their valence faster by pressing a key on the right side of a keyboard with the dominant right hand. In contrast, they judged negative words faster by pressing a key on the left side with the non-dominant left hand. Lefthanders, on the contrary, did the opposite (de la Vega, Filippis, Lachmair, Dudschig, & Kaup, 2012; Kong, 2013). Yet, a follow-up study demonstrated that crossing the hands on the keyboard (e.g., dominant right hand responding on the left side and non-dominant left hand responding on the right side) still facilitated responses to positive words faster with the dominant hand and to negative words faster with the non-dominant hand (de la Vega, Dudschig, De Filippis, Lachmair, & Kaup, 2013). This finding suggested an affective connotation of the hands (i.e., dominant hand positive and non-dominant hand negative) rather than of the spatial locations, where the hand responses took place. Nonetheless, exploration in more detail revealed that this affective hand connotation might not entirely depend on the dominance of the used hand, but also on the movements that the subjects direct to the right or the left space (Milhau, Brouillet, & Brouillet, 2015). This time, affective words were presented on a monitor screen, and two groups of right-handed participants judged their valence by responding only with their dominant right hand on a keyboard, whereas two further groups used only their non-dominant left hand. In addition, half of the participants responded to the positive (negative) words by releasing a key at a centered position of the keyboard and pressing a key at the right (left) side. The other half responded to the positive (negative) words by pressing a key on the left (right) side. The crucial finding was that positive words were judged faster with movements of the dominant right hand to the right side, but also with the non-dominant left hand to the left side. A similar pattern of results was observed for left-handed participants. The authors interpreted these results to indicate that rather than being fixed, the affective connotation of the hands would be modulated by their spatial motor fluency, like in tasks involving lateral movement (cf. Casasanto & Chrysikou, 2011).

Against this backdrop, one may argue that processing the valence of an affective stimulus would be congruently associated with affective motor responses of the dominant and non-dominant hand (de la Vega et al., 2013), or in contrast, with affective lateral movements of the hands to the right or left space (Milhau et al., 2015). However, in light of the embodiment findings suggesting that physical actions may influence affect, it is surprising that very little is known about whether these affective associations with hand dominance or lateral movements could be linked to any difference in influence upon appraisals towards valence–laden objects. Moreover, beyond hand responses to affective words on keyboards, it is quite unclear what to expect when actions of the non-/dominant hand are more naturally performed in direct contact with an affective object or when lateral movements of the hands integrate both the dominant and the non-dominant spaces (cf. Casasanto, 2009; Hayes et al., 2008). Therefore, we propose that such potential effects should be examined where performing actions in the lateral space with hand or arm movements have increasingly become a central aspect, without regard to any particular object grip. Touchscreens (e.g. tablets or touchscreen monitors) provide such an environment. Indeed, the advent and increasing use of touchscreens raise questions about if and how interacting through these interfaces may affect users' cognitive and emotional experiences (e.g., Gao, Bianchi-Berthouze, & Meng, 2012; Shah, Teja, & Bhattacharya, 2015). Some studies also suggest that using a touchscreen as an experimental paradigm may have applications in more physical action situations, such as findings on affective processing using external devices like keyboards or joysticks have indicated (e.g., Bamford & Ward, 2008; Jacob et al., 2008; Kraus & Hofmann, 2013). Furthermore, touchscreen devices have been characterized as "natural user interfaces", because users interact directly with digital contents (e.g., pictures) using rather natural finger-, hand- and arm movements, similar to real actions with physical objects (Wigdor & Wixon, 2011). Accordingly, in the study presented here a touchscreen monitor was used where right-handed participants were instructed to execute a single action involving the lateral movement of positive and negative emotional pictures, either with their dominant right or their non-dominant left hand. In particular, the movements were performed either from the right to the left side of the interface or from the left to the right side. In other words, this setting leads to a dissociation between the starting and end-points of the movement, which were spatially situated opposite each other. However, the complexity inherent in this experimental setting required integrating the BSH framework into a broader theoretical perspective to account for the potential affective consequences of an action (cf. Brouillet, Milhau, & Brouillet, 2015). For example, the Theory of Event Coding (TEC; Hommel, Müsseler, Aschersleben, & Prinz, 2001) proposes that planning or executing an action integrates the mental representation of feature codes from both the perceptual stimuli and the outcome of an action. With regard to this study, planning interactions with valence–laden emotional pictures on a touchscreen monitor could stimulate the selection, activation, and integration of their positive or negative valence codes. However, such interactions could also stimulate affective codes associated with the non-/dominant hand, as well as with lateral movements performed from right to left or from the left to the right space. This could lead to a potential conflict of concurring reference frames, namely, one according to hand dominance and one according to lateral arm movement. Accordingly, if lateral arm movements of the dominant or non-dominant hand (and not only hand dominance) influence the valence appraisals towards the pictures, we would expect interactions between hand (left or right), movement (right to left or left to right) and valence category (positive or negative; hand-and-movement-hypothesis). The second possibility is that there would only be an interaction between hand and the valence category of the stimuli, independently of the kind of movement performed with the dominant or non-dominant hand on the pictures. This would provide evidence for hand dominance as the only bodily aspect influencing the valence appraisals (hand-dominance-hypothesis).

Method

Participants

A total of 120 right-handed participants (M_{age} = 25.2, SD = 7.6; 78.3% women) took part in the experiment in exchange for monetary reward. Informed consent was signed prior to participation in the study. Handedness was tested with the Edinburgh Inventory (Oldfield, 1971), in German translation, modified by Salmaso and Longoni (1985).

Apparatus and stimuli

A large-scale touchscreen monitor (TM; Dell^{TM}-Monitor S2340T) connected to a computer (Lenovo ThinkPad T410, Intel Core i7 620M, 2.67 GHz) was used to display the stimuli. The TM was 23 inches [20.99″ (V) × 12.28″ (H) Activ-Matrix-TFT-LCD] and featured a resolution of 1600 × 900 pixels. Forty pictures from the International Affective Picture System[1] (IAPS)) were used as stimuli. According to the IAPS' valence ratings, 20 pictures were categorized as positive (e.g., animals and families) and 20 as negative (e.g., aggressive faces). All the pictures had neutral arousal on average. An ANOVA on the pictures' valence means confirmed differences between the valence categories ($M_{positive} = 7.22$, $SD_{positive} = 0.53$; $M_{negative} = 2.77$, $SD_{negative} = 0.53$), $F(1, 38) = 595$, $p < 0.001$. Pictures' arousal means, on the contrary, did not show any significant differences ($M_{positive} = 4.86$, $SD_{positive} = 0.39$; $M_{negative} = 5.03$, $SD_{negative} = 0.49$), $F(1,38) = 1.46$, $p = 0.15$. Pictures were presented on the TM with a resolution of 397 × 340 pixels (10.5 cm × 9 cm), at a distance of 42 cm to a white square (6.2 cm × 6.2 cm).

Procedure

To control for the differences within and between the experimental groups, participants evaluated the valence of the pictures 48 h before the experiment. Once in the laboratory, participants were randomly assigned to one of four experimental groups. Two groups of participants touched the pictures only with their dominant right hand. One of these groups touched and moved the pictures with their right hand from the right side of the TM to the left side, where a white square indicated the movement endpoint. The other group touched and moved the pictures with their right hand from the left side of the TM to the right side. Two further groups of participants performed analogous movements using only their non-dominant left hand (see Fig. 1). After each lateral movement the picture just moved disappeared, then it appeared again in the middle of the TM together with a Likert scale below it. Here participants had to evaluate the picture using numbers between 1 (low valence) and 9 (high valence). Immediately after this evaluation, the next picture was presented. The order of all of the pictures was randomised. This procedure made it possible to compare the unilateral influence of each hand interaction or lateral movement on the valence evaluation of the stimuli.

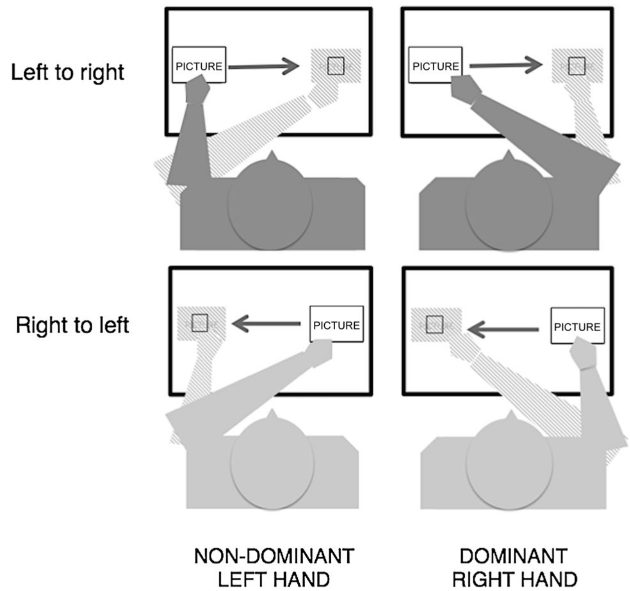

Fig. 1 The figure represents the four experimental groups (each group had 30 subjects). In two groups, participants used the dominant right hand (right side of the figure); the other two groups used the non-dominant left hand (left side of the figure). Participants touched and subsequently moved the pictures on the touchscreen monitor either from left to right (dark grey) or from right to left (light grey). Dashed areas represent the final arm and pictures' positions

Data analyses

All analyses were performed using a linear mixed-effects model (LMM) via maximum likelihood (ML) with the software package SPSS 21.0 (IBM). This method is particularly appropriate for controlling the error variance of subjects, stimuli and subject by stimuli interactions simultaneously. Furthermore, LMM allows for more flexible handling of unbalanced data, outliers or missing observations, in contrast to the traditional analysis of variance (e.g., Baayen, Davidson, & Bates, 2008; Barr, Levy, Scheepers, & Tily, 2013). Accordingly, valence evaluations greater or less than 3 SDs of the subject average in the positive and negative pictures' categories, and the picture average in each experimental group were excluded from further analyses (2%). The modelling of the resulting data, as elaborated next, reached a better fit (AIC = 14430.8)[2] compared to a random-factor-only model (i.e., including subjects and pictures intercepts only; AIC = 16337.3), $\chi^2 = 20.09$, $p < 0.01$. To calculate p values estimates for the fixed-effects, it was used a Type

[1] The following pictures were used as stimuli: Positive (1340, 1811, 1920, 1999, 2154, 2209, 2311, 2340, 2346, 2352, 2362, 2373, 2391, 2398, 2550, 2900.2, 4250, 4520, 5628, 8500). Negative (1111, 1270, 1274, 2120, 2141, 2205, 2375, 2692, 2710, 2800, 3350, 6242, 9000, 9090, 9280, 9342, 9417, 9440, 9560, 9911).

[2] Akaike's Information Criterion (AIC) is an indicator of the relative quality of statistical models, with the interpretation that a smaller form is better. It takes into account the model accuracy regarding the explained variance and the model complexity regarding the number of predictors included.

III Satterthwaite approximation (e.g., Carr, Rotteveel, & Winkielman, 2016; West, Welch, & Galecki, 2014).

Valence evaluations were analyzed with a 2 (hand: right vs. left) × 2 (movement: right to left vs. left to right) × 2 (valence category: positive vs. negative), fixed-effects structure. Hand and movement were manipulated between subjects, whereas valence category was manipulated within subjects. Valence evaluations of the baseline were used as a control covariate. Subjects and pictures were included as random factors with random intercepts to account for between-subjects and between-pictures differences on the valence evaluations.

Results and discussion

The analysis showed a significant main effect of hand $F(1,117) = 7.9$, $p = 0.006$, indicating that the pictures' evaluations were more positive after moving them with the dominant right hand than with the non-dominant left hand. The main factor movement showed also a significant effect, $F(1,117) = 5.4$, $p = 0.022$, indicating that right-to-left movements led to more positive picture evaluations than left-to-right movements. Not surprisingly, the valence categories of the pictures also differed significantly, $F(1,68) = 451.5$, $p < 0.001$, indicating that positive pictures led to more positive evaluations than negative pictures.

The two way interactions between hand and movement ($F(1,117) = 1.7$, $p = 0.19$), hand and valence category ($F(1,4529) = 1.3$, $p = 0.24$) and movement and valence category ($F(1,4531) = 0.17$, $p = 0.67$) were not significant. However, the significant main effects were qualified by a highly significant three-way interaction between hand, lateral movement and valence category, $F(1,4529) = 10.7$, $p = 0.001$ (see Fig. 2).

To gain further insight into the findings, the results with regard to the influence of the hand used to interact with the pictures will be described below.

Dominant right hand

Interaction with positive pictures by the dominant right hand led to more positive evaluations after right-to-left movements than after left-to-right movements, $t(241) = 1.99$, $p = 0.047$, $d = 0.26$. In contrast, interaction with negative pictures by the right hand did not result in any significantly different evaluations between the same lateral movements, $t(218) = 0.81$, $p = 0.42$. This suggested, first of all, that the influence of the lateral movement on the touchscreen might have been determined by the right space from where the positive pictures were initially touched. Secondly, this result also suggested that when the valence codes of the positive pictures were combined with the dominant right hand as well as movements from the participants' dominant right side, there was valence evaluation reinforcement of the positive pictures.

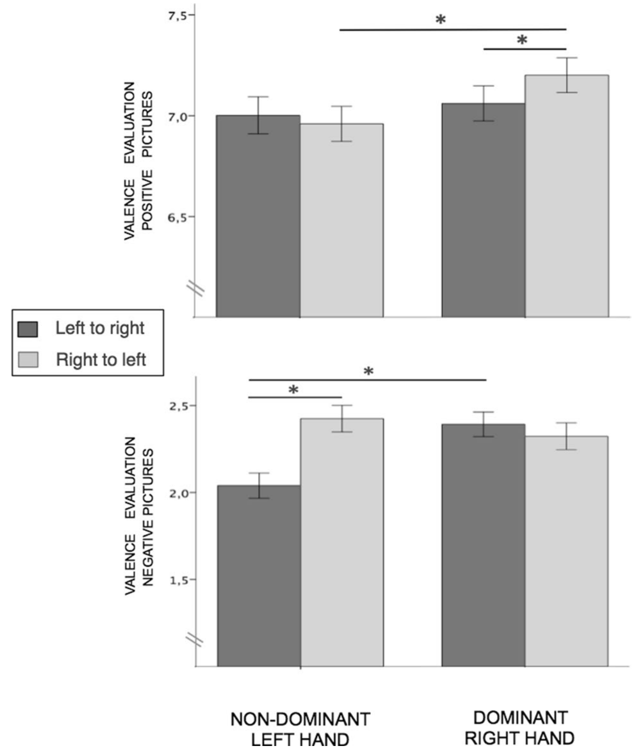

Fig. 2 Valence evaluations of positive pictures (upper portion) and negative pictures (lower portion) after lateral movements of the dominant right hand and the non-dominant left hand. Vertical bars indicate 95% confidence intervals. Asterisks represent significant effects at the level of $p < 0.05$

Non-dominant left hand

Interestingly, interaction with positive pictures by the non-dominant left hand did not result in any significant differences between the performed lateral movements $t(238) = 1.1$, $p = 0.23$. However, interaction with negative pictures by the left hand led to more negative evaluations after left-to-right movements than after right-to-left movements $t(217) = 3.3$, $p = 0.001$, $d = 0.73$. This suggested that, in this case, the influence of the lateral movement on the touchscreen could have been determined by the left space from where the negative pictures were initially touched. Accordingly, when the valence codes of the negative pictures were combined with the non-dominant left hand, and movements performed starting from the participants' non-dominant left side there was valence evaluation reinforcement of the negative pictures.

In addition, when comparing the effects between the hands, it appeared that moving positive pictures with the dominant right hand from the dominant right side of the

Table 1 Valence evaluation effects stemming from the match between the positive or negative valence codes (in parentheses) associated with (1) the dominant right or non-dominant left hand, (2) picture's valence category, and (3) lateral arm movement from the dominant right or the non-dominant left space of the touchscreen monitor

	Pictures' Valence category			
	Positive (+)		Negative (-)	
Movement's starting side / *Hand dominance*	Left (-)	Right (+)	Left (-)	Right (+)
Dominant Right Hand (+)	Attenuation	Reinforcement	n.s.	n.s.
Non-dominant Left hand (-)	n.s.	n.s.	Reinforcement	Attenuation

Note: n.s. (no significant differences)

touchscreen resulted in more positive evaluations than using the non-dominant left hand $t(240)=2.6$, $p=0.010$, $d=0.43$. Interestingly, moving negative pictures with the non-dominant left hand from the non-dominant left side resulted in more negative evaluations than when the dominant right hand was used, $t(218) = -3.3$, $p=0.001$, $d=0.73$. This result supported the idea of a valence matching among the three factors.

To sum up, these findings indicated a reversed pattern of results. More concretely, they suggested that a matching among the valence codes of the three factors (hand, movement and valence category of the pictures) resulted in reinforcement of the valence category of the picture that was moved (i.e., positive pictures were evaluated more positively and negative pictures more negatively). In contrast, a valence matching between only two of the factors resulted in a valence attenuation of the picture that was moved (see Table 1).

General discussion

Embodiment approaches to interactive technologies are increasingly concerned with the question of how physical interactions in such environments may influence user's affective experiences (cf. Farr, Price, & Jewitt, 2012). Along this line of reasoning, the purpose of the study presented here was to investigate whether direct interactions with valence–laden emotional pictures in a touchscreen environment would influence the subjects' subsequent valence appraisals towards the pictures. Specifically, this study is based on findings derived from the BSH as a theoretical framework (BSH; Casasanto, 2009). These findings suggest that affective valence is associated with motor responses to actions by the dominant and non-dominant hand (i.e., dominant—positive and non-dominant—negative; cf. de la Vega et al., 2013) or, in contrast, with lateral movements of the hands (i.e., right hand to the right—positive and left hand to the left—positive; cf. Milhau et al., 2015). Accordingly, it was examined the potential affective influence on participants' appraisals towards the pictures due to actions performed with the dominant or non-dominant hand, or due to their related lateral movements to the right or left space. To test this, right-handed participants touched positive and negative IAPS pictures and moved them only with their dominant right or their non-dominant left hand. Taking into consideration the original space–valence associations reported in the BSH (i.e., dominant space—positive and non-dominant space—negative), the movements were performed either from the dominant right to the non-dominant left side or from the non-dominant left to the dominant right side of a large-scaled touchscreen monitor (TM). All factors were investigated between participants, except the valence category of the pictures, which was tested within participants. It was hypothesised that if not only hand dominance, but also lateral movements of the hands influenced valence evaluations of the pictures, a further interaction between hand (left or right), movement (right to left or left to right) and valence category of the pictures (positive or negative) would be expected (hand-and-movement-hypothesis). However, if only hand dominance influenced valence evaluations of the pictures, interaction between hand and valence category of the pictures was expected (hand-dominance-hypothesis).

The findings of this study showed interactions between hand, lateral movement and valence category. Specifically, the results show first, that positive pictures moved with the dominant right hand and negative pictures moved with the non-dominant left hand were evaluated more positively after right to left than after left-to-right movements. In other words, pictures were evaluated more positively only if they were moved (1) with the hand that was congruent with the valence category of the picture that had been moved (i.e., "positive" dominant hand—positive pictures—and "negative" non-dominant hand—negative pictures) and (2) starting from participants' "positive" dominant right space. Although this supports the view of the BSH by Casasanto (2009), it is at the same time evidence that hand dominance is not the only driving factor in this setting.

The second intriguing finding of this study is that positive pictures moved with the dominant right hand from right to left were evaluated more positively than those moved by the non-dominant left hand, whereas negative pictures moved with the non-dominant left hand from left to right were evaluated more negatively than those moved by the dominant right hand. This result reflects a "valence–reinforcement" effect, a reinforcement of the valence category when participants evaluated the pictures. This effect was caused by the two following conditions: (1) using the hand that was congruent with the valence category of the picture being moved (i.e., "positive" dominant hand - positive pictures and "negative" non-dominant hand - negative pictures) and (2) starting the movement from the space that matched the hand (i.e., positive dominant hand—positive right space surrounding the right hand and negative non-dominant hand—negative left space surrounding the left hand). Thus, negative pictures were evaluated more negatively and positive pictures more positively, supporting the hand-and-movement-hypothesis of this study.

Interestingly, although this valence–reinforcement effect is consistent with previous findings of embodied emotion research (e.g., Clore & Schnall, 2008), it is rather hard to explain exclusively within the BSH framework. For example, according to Milhau et al., the most plausible prediction would be that movements with the right hand towards the right side of the touchscreen or with the left hand towards the left side of the touchscreen (i.e., fluent movements with the preferred hand) would lead to more positive evaluations. This prediction is not supported by our study's results. It is important to remark, however, that in the studies by Milhau et al., or de la Vega et al., participants were presented with words in the middle of a screen, and also that the mapping of the key responses (e.g., right key positive and left key negative, or vice versa) or the scale used to judge the stimuli' valence were pivotal factors. In contrast, the pictures used in our study were all initially presented either on the right or the left side of the touchscreen for participants to interact with them directly from these positions. Therefore the pictures were not presented according to space–valence mappings (e.g., right picture—right side and negative picture—left side or vice versa) making a priori more difficult to perceive such associations.

Reconsidering the movement that participants were instructed to make may shed more light on the effects reported in the study here. For example, considering the movement of the right hand from right to left. First, the right hand was not statically located at the right side of the touchscreen, i.e., the picture did not automatically appear below the hand. Thus, to move the picture, it was first necessary to guide the hand to the stimulus and touch it. After this action was taken, the stimulus was then moved from its initial right location to the target on the left side of the screen. Therefore, we have two different movements: one from the initial point of the trial (centre of the screen) towards the picture (to the right side of the screen) to touch the picture; the other when the picture was moved from right to left to reach the target on the left side of the touchscreen. To understand what mechanism is at work here, it may help to reconsider the movement instructions of the paradigm in a broader framework than the BSH, for example, from the Theory of Event Coding (TEC; Hommel, 2015; Hommel et al., 2001). TEC suggests that when planning or executing actions, subjects create mental representations in the form of feature codes. In the study presented here these codes may correspond not only to the pictures' valence category, non-/dominant hand or movement' starting side, but also to the consequences of the actions that participants planned or executed (cf. Eder, Müsseler, & Hommel, 2012).

According to this rationale, the actions directed by the paradigm obviously have two parts as two different events. The first refers to the event where the picture is touched and the second refers to the event where the picture is moved from its initial location to the target. From this perspective, it is conceivable that the touch event also had influence on subsequent valence appraisals rather than only the target event. A reason for why this could be is provided by studies showing that moving the hand towards a visual stimulus may direct attentional processes, leading to enhance the processing of the stimulus itself (e.g., Abrams, Davoli, Du, Knapp, & Paull, 2008). Accordingly, this could make the touch event important for subsequent valence evaluations. This is supported by the employed paradigm: in contrast to the repeated movement to reach the target (affective neutral square), touching each picture is in each trial a different event because of the randomly presented stimuli that have either positive or negative valence. This could be a difference between the touch event and target event, especially when the affective codes corresponding to all three factors, i.e., hand, side and valence of the picture, match (e.g., positive: right hand, right side, and picture). In light of TEC, it appears, then, that the appraisals of the pictures' valence seem to depend on the resulting feature code determined by the touch event.

To sum up, the results support the view that the affective codes of all three factors, valence category, hand dominance, and lateral movement influence valence appraisals of positive and negative pictures. However, with regard to the movements, this study cannot disentangle whether it is the movement towards the stimulus, or touching the stimulus itself, or moving the stimulus away from the touch point, which drives the valence–reinforcement effect. Several follow-up studies could help to answer these questions. For example, it could be investigated if the valence–reinforcement effect would also be shown if the hands (left or right) were statically located on the left or the right side of the touchscreen, so that the stimulus which automatically appeared below the hand would then have to be moved to the opposite side. Although this action is rather less natural when using touchscreens, this could help to clarify if the first movement is important for the effect. A further study could investigate if moving the hand towards the stimulus without moving it afterwards to the target would be sufficient for the valence–reinforcement effect. This could be studied in more detail by letting the picture disappear immediately after the touch. To investigate if the touch directly upon the stimulus is important, a study should be employed where participants touch the screen but not the picture. The movement would then be executed not directly on the picture but with an offset towards the lower or upper edge of the touchscreen. All these studies would contribute to further clarification of the mechanisms behind the valence–reinforcement effect when using a touchscreen interface. In this regard, a further limitation of the study presented here is that the affective influence of the wide arm movements involved crossing the body midline because of the size of the screen. Accordingly, the findings cannot be directly generalised to other touchscreen devices with smaller dimensions. Thus, it would also be interesting to examine whether valence–reinforcement would appear using other, smaller touchscreen environments, for example, smartphones and tablets. Although arm movements should rather step back in such small environments it is conceivable that the touch event becomes more prevalent. If so, it would be nevertheless interesting to examine whether lateral movements performed with the fingers would cause similar effects than in the present study.

Conclusions

The results of this study conducted using a large-scale touchscreen environment suggest that beyond the valence category of the emotional pictures that one acts upon, the affective connotations attributed to the dominant or non-dominant hand and the kind of interaction with lateral movements will influence an affective experience as reflected in valence appraisals towards the pictures. Moreover, the valence–reinforcement effect which appeared suggests that findings stemming from the BSH (Casasanto, 2009; de la Vega et al., 2013; Milhau et al., 2015) could be integrated into a broader framework of action planning accounted for by the Theory of Event Coding (TEC; Hommel et al., 2001), as when the participants acted upon the stimuli. Beyond action execution measured by means of response latencies, these novel findings suggest that the TEC could also be useful to predict subjects' affective appraisals towards stimuli. To our knowledge, this is an aspect, which has not been investigated so far in any comparable setting.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the Helsinki declaration 1964 and its later amendments or comparable ethical standards. The manuscript does not contain clinical studies or patient data, and informed consent was obtained from all individual participants included in the study.

Conflict of interest The authors declare that they have no conflict of interest.

Informed consent Informed consent was obtained from all individual participants included in the study.

Data availability The dataset generated during and/or analyzed during the current study are available in the Figshare repository, https://figshare.com/s/b6c4e44d57b0b59204bc, https://doi.org/10.6084/m9.figshare.5457268.

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