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Attribution of feature magnitudes is influenced by trained reading-writing direction

Ulrich von Hecker[a], Zahra Arjmandi Lari[b], Masoud Fazilat-Pour[c] and Lea Krumpholtz[d]

[a]School of Psychology, Cardiff University, Cardiff, UK; [b]School of cognitive science, IPM, Tehran, Iran; [c]Faculty of Education and Psychology, Shiraz University, Shiraz, Iran; [d]Universität Mannheim, Mannheim, Germany

ABSTRACT
Spatial configurations amongst stimuli can influence magnitude attributions. Someone's acquired reading and writing direction (RWD) can provide a spatial schema of *primacy* extending from left (maximum) to right (minimum) for Westerners and opposite for leftward RWD languages. Primacy information can be transformed into a magnitude attribution regarding a feature quality, perceiving an object as having "more" of a certain quality for Westerners when positioned *left* amongst two similar objects, likewise when positioned *right* for people with a right-to-left RWD. Results showed that native English speakers tended to attribute greater magnitude of a given feature in fictitious products displayed *left* within a pair, indicating which of two products was "most" representative of a certain quality (Experiment 1a) but they would randomly choose when asked which product represented "least" of the quality (Experiment 1b). A similar, but reversed pattern of effects was obtained for Farsi participants only familiar with Farsi (Experiment 2).

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In most cultures, people read either left-to-right or right-to-left, and this habit might affect the processing of other stimuli outside reading or writing. Such processing may associate "left" with higher *primacy* than "right", or vice versa. High-primacy stimuli (seen more as "left", or vice versa) may then be attributed features with greater intensity or magnitude, than low-primacy stimuli. We aims at reporting evidence for these ideas.

Space can imply meaning

Recent research shows that physical parameters of stimulus presentation, especially orientation of stimuli in space, can have implications for interpretation of the same stimulus. For example, target concepts/objects shown at higher spatial locations (as compared to lower spatial locations) are identified easier and faster as powerful, or of positive valence (Meier & Robinson, 2004; Schubert, 2005). Likewise, target persons, objects, and scenarios shown on the left side in a display (as compared to the right side) are more often associated with initiative, forcefulness, i.e. agentic characteristics in general (Suitner & Maass, 2016). The theoretical idea underlying this research is that, in the sense of weak embodiment (Boroditsky & Ramscar, 2002), abstract, spatially based schemata are invoked by the semantics of a certain class of stimuli or task. According to this, stimuli carrying power-related meanings (Schubert, 2005) will invoke a vertical hierarchy schema. As well, valence-related stimuli will invoke a vertical schema of good vs. bad (Meier & Robinson, 2004). Stimuli carrying an agency-related meaning (athletes, pictorial presentations of social interactions) will invoke a hoizontal schema of abstract agency (Suitner & Maass, 2016; Tversky et al., 1991). When the meaning of the stimuli by itself implies an order, as in case of numbers, this will invoke a horizontal order schema as well, with small numbers represented on the left and larger numbers

CONTACT Ulrich von Hecker vonheckeru@Cardiff.ac.uk

represented on the right, for Westerners (Dehaene et al., 1993). In the present research we limit our considerations to the horizontal case, and we will ask a novel, reversed question: Can spatially represented order implications be translated into magnitude attributions with respect to object features? We ask this question assuming that stimulus *meaning* may be irrelevant for that spatial implication. We will first develop the theory behind the assumptions so far, before turning to our own, novel predictions.

Spatial primacy in the horizontal case

In general, arguments for the contribution of spatial processes in forming mental representations often rest on the demonstration of lateral asymmetries. In particular, the learned reading/writing direction (RWD) is often assumed to be the basis for such asymmetries. For example, English-spoken participants (left-to-right RWD) spontaneously mapped a sequence of events (such as the meals of the day) onto a horizontal line directed rightward, placing earlier events to the left and later events to the right (Fuhrman & Boroditsky, 2010). This tendency was reversed in Hebrew-speaking participants (right-to-left RWD). Spanish speakers responded faster when making judgments on whether words refer to the past or the future when past-related words appeared left and future-related words appeared right on a screen (Ouellet et al., 2010; Santiago et al., 2007). In Dutch-speakers, months close to the beginning of the year were responded to faster with the left hand than with the right hand, whereas the opposite was found true for months toward the end of the year (Gevers et al., 2003). Tversky et al. (1991) had children order pictures into temporally ordered stories and found a tendency to order these from left to right in English-speaking children (left-to-right RWD), whereas this tendency reversed in Arab and Hebrew children who were used to right-to-left-written languages. However, preliterate kindergarteners did not show any such spatial biases (Dobel et al., 2007) which again hints at the tight connection between RWD and the orientation of the mental time line.

The explanations so far focus on the idea that the learned reading/writing direction (RWD) is used as an abstract template which a primacy dimension can be mapped onto. So, for example, for the time line in Westerners, it is assumed that the semantics of the stimulus (e.g. events in a story, elements of a sequential action, etc.) Automatically access a leftward schematic representation, abstracted from the action implication of reading/writing: In the West, one starts from left and goes rightwards. This schema implies an action hierarchy, and therefore, if transformed into a more general action schema, will imply an abstract order dimension (cf. Suitner & Maass, 2016). In our own previous experiments we studied learned order hierarchies, e.g. A > B>C … etc., with letters standing for a hierarchy of target persons of different age, wealth, strength, or other abstract characteristics. Western participants were more likely to correctly identify the dominant element in a randomly chosen pair (e.g. A in A > B), and to be quicker for correct responses, if the dominant element was displayed to the left of the non-dominant element (as compared to a display on the right). This effect reversed in an Iranian sample (right-to-left RWD, von Hecker et al., 2016). In line with findings from a variety of paradigms (see also Chatterjee, 2001; Dehaene et al., 1993; Tversky et al., 1991; Zebian, 2005), we explained this as showing that, for Westerners as well as for Iranians, the acquired reading/writing direction (RWD) provides an abstract concept of *spatial primacy* extending from left (maximum) to right (minimum). In an actual episodic context, this concept is then triggered by the meaning of the relational stimuli, as these were learned as pairs of an implied order hierarchy (e.g. A > B, B > C, … , etc.). Stated differently, the semantics of the stimuli would invoke an available spatial schema for ordering, in terms of RWD. In consequence, a stimulus presentation that is perceived as congruent with the invoked spatial schema (i.e. a horizontal pair arrangement showing the dominant element at the side closer to the RWD origin) would be easier to process than a incongruent presentation, that is, showing the spatially reversed arrangement (i.e. dominant element on the side farther away from the RWD origin). Congruent presentations, therefore, are expected to promote a processing advantage over incongruent ones, leading to quicker (and more correct) responses.

How spatial primacy is anchored

We argue that the dimensional maximum (not the minimum), representing maximal magnitude in a given context, is placed at the RWD origin, through metaphorically blending spatial primacy with the dominant end of the dimension (see

Carney & Banaji, 2012; Casasanto, 2009): "The first in a series (or a pair) is the leftmost (…). Linguistic expressions like 'the prime example' conflate primacy (magnitude) with goodness (i.e. this phrase can mean the first example, the best example, or both). Speakers of languages like English may be predisposed to consider the left-most item to be the first and therefore the best". (Casasanto, 2009, p. 362). "Conceptual Blending" is defined here, following the linguistic literature, as the integration of information from disparate domains. When two concepts are blended, overlapping aspects of their individual meanings form the core of a new, enhanced, or pragmatically more useful, integrated meaning (Coulson & Oakley, 2005; Fauconnier & Turner, 1998).

In this example, it is assumed that goodness is a magnitude or an asset, and that more goodness dominates less goodness.

Spatial primacy and magnitude attribution

In the present research, we take a new approach and ask a question which takes a reverse perspective, compared to the studies discussed so far, which is: Can spatial primacy *on its own* contribute information to the extent that a judgment on the magnitude of a (hypothetical) feature attribute may be influenced? In the research so far, spatial primacy appears to be invoked by the semantics of the very stimuli in question, and the relation between two stimuli is sufficiently determined by it. In other words, the meanings of those stimuli carry an order relation between them, *a priori*, by means of the information presented. For example, e.g. in a pair A B, element A may be presented as the *older* one than B, the *wealthier* one, the *faster* one or anything other using a quantifiable comparator term, be it concrete or abstract. In this situation, the presented, comparative information about the relation between A and B specifies the rank order between the two as through the presented feature quantity. This again can activate the notion of *primacy* in terms of the spatial order representation. The reverse question we ask here is, what happens in a reduced situation where A and B are not sufficiently specified attribute-wise, as to yield a clear order relation between them. Such a situation may be characterised, first, by the absence of any recognisable dimension that one could use, *a priori*, as diagnostic dimension to distinguish between A and B. Second, the situation may be such that nonetheless, an individual is asked to make a comparative judgment between A and B on a particular attribute dimension. Would then spatial primacy, by virtue of metaphoric blending, provide the information just needed? That is, would the positioning of element A closer than element B to the RWD origin in a pair, be blended to yield the attribution of "dominance" of A over B? If so, then at the time of testing, the process of response generation may draw on this particular source of information. In a horizontally presented pair, the element that is mentally represented *closer* to the RWD origin by means of spatial primacy, is likely to be seen as the dominant one. This primacy may in turn be translated into a magnitude attribution that can be interpreted in an ordinal sense.

Along these lines, we use horizontally presented pairs of fictitious consumer objects as example stimuli, and we ask whether schematic spatial primacy, as derived from the participants' RWD background, would be blended with the queried feature dimension and thus lead to the assignment of some positive quality as a hypothetically inferred (i.e. *not perceived*) stimulus attribute.

Practical relevance of a mechanism based on spatial primacy

The novel theoretical question addressed in the present paper is to what extent the spatial configuration *as such* (in which a stimulus occurs) can provide information that is ultimately attributed to the stimulus itself. We ask whether unspecific primacy information, derived from the spatial arrangement in the display, can inform a judgment about the magnitude of a concrete stimulus feature. The present question, over and above its theoretical importance, is also relevant to applied scenarios. Imagine displays that present more than one stimulus alongside each other in a horizontal setting, for example, a line-up of products in a visual advert, the positioning of products on a shelf, or the spatial arrangement of content vignettes on a website. It is possible that whatever a perceiver will take away from a perceptual episode, in terms of their understanding and appreciation of an object, a message, or indeed a product presentation, might be co-determined by the spatial arrangement of how the objects are placed within that spatial context.

Obviously, in many cases, spatial location as a cue will be competing against other diagnostic cues that are available in the situation, for example lateral fluency in left- vs. right-handedness (Casasanto & Chrysikou, 2011) or predominant food preferences (Romero & Biswas, 2016). But in time-pressed situations, or when selecting amongst options one isn't familiar with, the spatial positioning of the products may contribute primacy information, influencing decisions. A perceiver may be in a hurry, or for some reason may have to select amongst options s/he doesn't know very much about. If in such a situation a perceiver engages in browsing a horizontal visual display of items (products), the spatial placement of the products (via automatic, highly overlearned primacy implications as derived from RWD) may contribute information relevant to one's appreciation of a particular product, in relation to other products in the same display.

Experiment 1a: United Kingdom, dominant target

When faced with a horizontal pair of stimuli, participants without diagnostic cue for responding should use spatial primacy. When quality (X) is compared between two undistinguishable products ("which is MOST X?"), British participants should select the left-positioned product above-chance (H_1). If spatial primacy was not used, participants should select randomly; that is, select the left or the right product each, half of the time (H_0).

Method

Power considerations

A pilot experiment was run, having 61 Cardiff University students indicate "the word implying MOST dominance", for pairs of horizontally presented social role labels, such as "boss – secretary" (unambiguous) or "sovereign – monarch" (ambiguous). Only for ambiguous words, an effect size of Cohen's $d = .58$ was found in favour of selecting the left-presented word. We conducted a power analysis based on the above effect size, a one-sample *t*-test against a fixed parameter, two-tailed testing, stipulating a power of $1 - \beta = .95$ and an alpha-level of .05 (GPower 3.1.3., Faul et al., 2009), yielding a minimal required sample size of $N = 41$. Taking a conservative approach on the basis of this analysis, we planned for a minimum of $N = 45$ participants[1].

Participants

45 students from Cardiff University participated in this study. (40 female, mean age: 20.5 years), all with English-spoken backgrounds, took part in the experiment in return for course credit or monetary payment. The experiment had received ethics approval from Cardiff University Ethics Committee.

Materials

Twenty images of fictitious products were designed for the purpose of this research by the first author in collaboration with the University of South Wales' School of Marketing and Design (at Cardiff). There were four product categories with five individual product images in each category. Images within a product category were created using neutral color palettes (avoiding salient color associations) and having very similar hues of the same color (see an example in Figure 1). Each product had a subtle distinguishing feature, that is, a symbol which by itself would not be diagnostic of any particular quality. For example, the essential oil stimuli differed in the type of droplet, number of ripples or lines presented in their centre. All images were presented on white square backgrounds, superimposed onto black screens in both the learning and testing phase (see below).

Procedure

The experiment had four blocks, corresponding to the four product categories. Each block had a learning phase and a testing phase. In the learning phase, participants were shown all five products in a horizontal display. Each product had a fictitious chemical ingredient written underneath, for example: "CAPRYLEHYDE", or "OXYSOHEXYL". This was done to support the cover story instructions which were to learn the associations between the different products and the chemical ingredients. This should also support the impression amongst participants that there was actually a way of rationally distinguishing the products within a given category, even if their

[1]As a limitation of the present approach at calculating power, note that in the pilot study, no polarity between "the word implying MOST dominance" and "the word implying LEAST dominance" is realized, as which conceptual opposition is indeed a feature of the main experiments. Magnitude attribution is therefore only operationalized for the positive (unmarked) side of the dimension.

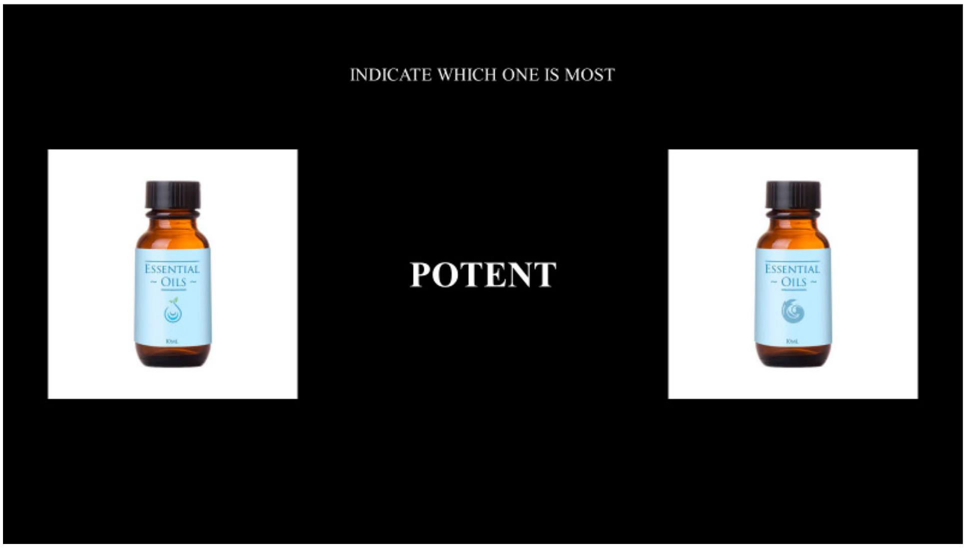

Figure 1. Example of the materials used in all experiments during the test phase: Two exemplars from the Essential oils category in display mode for testing.

learning of these associations would not be perfect. The instructions stressed further that there were subtle features that would allow a distinguishing between all five products. Actually however, the task instructed for the learning phase was not of real interest to analysis, and generated no data. The learning phase only served to familiarise participants with the type of stimuli to be used in the test phase. There was also a fictitious "check-up" after participants had ended the viewing of the product spread via a key pressing. In the check-up, participants were presented with each of the five products of that category, in isolation on the screen. The product was flanked, left and right, with two of the fictitious chemical ingredient names, one of them being the correct one, with the position of the correct one being randomly determined. Participants had an A4 sheet of paper in front of them and were asked to list "left" or "right" to indicate the correct position of the ingredient that they thought they had seen in combination with the product. The sequence of presenting the horizontal spread of five products, and then the check-up, was repeated once.

In the test phase, each of the products previously presented in the learning phase was paired with each of the other products to yield a series of all possible pair combinations. For one sequence of test presentations, in each trial, a pair was laterally presented on a black background at a distance of 25cm between the centres of each individual image, on the screen. Between the two images a comparator adjective at 36 font size appeared in white capital letters. Comparator adjectives were for the four product categories: "WARMING" (Scented candles), "POWERFUL" (Reed diffusers), "REFRESHING" (Incense sticks), and "POTENT" (Essential oils). All pairs in a product category were presented in a newly generated random sequence for each participant, and the sequence of product categories (experimental blocks) was also determined at random for each participant. Using the specially-marked "1" and the "9" keys on the keyboard with the forefingers of both hands, the task for participants was to indicate the one product in the pair that they thought was the dominant one, between the two, on the comparator dimension. There was no time limit for this response. To support the response, the words "INDICATE WHICH ONE IS MOST" were written in white capital letters at the top of the black background on which the pairs and the comparator word were shown (see Figure 1). After running through a first sequence of all possible pairs (10) at testing, a second sequence of all possible pairs (10) was seamlessly run immediately afterwards. For the first sequence, the lateral positioning of the images within a pair had been randomly determined, whereas for the second sequence, the laterality assignments within each pair were just reversed. This way, each product was compared to each other product twice across both test trial sequences for a total of 20 comparisons, and these comparisons occurred with each particular product shown on the left as well as on the right side within a pair, across the 20 trials. The experiment took approximately 20 minutes, including instructions and debriefing.

Results and discussion

The data and R scripts for analysis are available for download at https://osf.io/ev9z4/?view_only=feb68e8c0bdd4ead9de25c8efd22d017.

One participant was excluded from analysis on the grounds of perfectly uniform behaviour, that is, always "left" or always "right" in a given block. In order to test our hypothesis of a higher selection rate of the *left*-shown product than by chance alone, left key presses were counted for each block, that is, for each product category. Table 1 displays the descriptive statistics obtained for the individual experimental blocks as well as across all blocks. Response times were on average close to 1 second and are displayed in Table 1 as well.

A one-sample t-test was conducted on the average number of left key presses across all four blocks against 40 (expected value under random selection for four product type blocks with 20 trials each), in order to determine whether there was a statistically significant tendency to select the product displayed on the left side. "Left" responses were more often selected than expected by chance, $M = 45.66$, $SD = 6.67$, $t(43) = 5.63$, $p < .001$, $d = .85$. Participants generally considered the product displayed on the left side of the screen as being greater in magnitude with respect to the comparator than the one displayed on the right side, supporting the alternative hypothesis.

For each block separately, the number of "left" responses out of 20 trials was compared to the chance value of 10, using one-sample t-tests. Results were as follows: Left key presses for Essential oil (comparator: "potent"): $t(43) = 3.50$, $p < .001$, $d = .53$; left key presses for Incense sticks (comparator: "refreshing"): $t(43) = 3.39$, $p = .002$, $d = .51$; left key presses for Reed diffuser (comparator: "powerful"): $t(43) = 3.70$, $p < .001$, $d = .56$; and left key presses for Scented candle (comparator: "warming"): $t(43) = 5.18$, $p < .001$, $d = .78$. Results indicated that the number of left key presses was greater than the chance level of 10 within each block.

To see whether results from the four blocks were different, we conducted a repeated measures analysis of variances with a Greenhouse-Geisser correction. There was no statistically significant difference in number of left presses between the four blocks, $F(2.47, 106.08) = 0.72$, $p = .516$, suggesting that the results did not vary across product type categories. We also calculated Bayes factors using the Bayes Factor package in R (R Core Team, 2013). According to Jeffreys (1961) classification scheme, the estimated Bayes factors ($BF_{10} > 100$) suggested extreme evidence for the alternative hypothesis across all blocks (see Table 1).

Conclusively, we found that in a situation in which discrimination between the fictitious products was difficult and could not be based on obvious diagnostic cues, participants raised and trained with left-to-right RWD had a tendency to select the left of two items.

Experiment 1b: United Kingdom, non-dominant target

Next, we tested for a similar influence when asking for the non-dominant product. Left-to-right RWD-raised participants should then be biased to the right-positioned product in a pair. "Left" being associated with primacy, they should preferably select the right-positioned product (H_{1_1}) when asked "which of the two products is LEAST X?". If spatial primacy information was not used, they should select randomly (H_0).

However, "most" as comparator focuses on the unmarked end of the magnitude dimension (e.g. "powerful"), whereas "least" focuses on its marked end (e.g. "powerless", see Hamilton & Deese, 1971). Judgments at the marked end tend to be more unreliable than at the unmarked end (Schriefers, 1990; Schubert, 2005), presumably because of the negativity entailed by the marked end, as known to draw reasoning away from the concept in question, reduce its accessibility, and to be more time-consuming (Kaup & Zwaan, 2003; MacDonald & Just, 1989). We (von Hecker et al., 2016) found a left-directed bias (for Westerners) when judging pairs using "taller" (unmarked end), but no spatial effect using "shorter" (marked end, lack of magnitude; see also Schubert, 2005, for similar asymmetries). For this reason, evidence for the H_0, if obtained, will be treated as informative in terms of the markedness distinction.

Method

Participants

46 students from Cardiff University participated in this study. (41 female, mean age: 19.5 years), all

Table 1. Experiment 1a, descriptive statistics of left key presses and response times obtained for comparator words in conjunction with "most" (indication of dominant target) in addition to Bayes factors and respective classifications according to Jeffreys (1961) in the UK (Cardiff). $N = 44$.

	Left key presses		Response times (msec)			
Block	*M*	SD	*M*	SD	BF_{10}	Classification
Essential Oil	11.30	2.45	1080.35	443.02	27.33	Strong evidence for H_1
Incense Sticks	11.14	2.23	1147.34	476.04	20.34	Strong evidence for H_1
Reed Diffuser	11.50	2.69	1143.48	493.29	46.26	Very strong evidence for H_1
Scented Candle	11.73	2.21	1090.88	414.99	3324.60	Extreme evidence for H_1
All blocks	11.41	1.67	1115.51	393.96	13374.64	Extreme evidence for H_1
Total presses	45.66	6.67				

with English-spoken backgrounds, took part in the experiment in return for course credit. The experiment had received ethics approval from Cardiff University Ethics Committee.

Materials and procedure

All materials and procedures were identical to Experiment 1a except that in the test phase, participants were asked to indicate, using the specially-marked "1" and the "9" keys on the keyboard, the one product in the pair that they thought was the non-dominant one, between the two, on the comparator dimension. To support this, the words "INDICATE WHICH ONE IS LEAST" were written in white capital letters at the top of the black background on which the pairs and the comparator word were shown.

It is important to note that the present operationalisation of markedness makes the assumption that the quantifiers "MOST" and "LEAST", in combination with the comparator adjective, create strong associations with the unmarked and marked ends of the dimension in question. We chose this kind of operationalisation over the alternative of asking for different comparators in the two opposing cases, for example "MOST WARM" versus "MOST COLD". The reason for this is that we wanted to keep the semantics of the dimension constant, in order to be sure participants would draw on the same dimensional representation. In general, as one can easily see, changing the comparators, e.g. asking for "OLD" vs. "YOUNG", can activate quite different associations with, e.g. old vs. young age, such that it would become unclear, under such circumstances, whether magnitude judgments would indeed be based on the same dimensional semantics.

Results and discussion

Two participants were excluded, one because it was later revealed that this person was familiar with a language based on right-to-left RWD. The second participant was excluded on the basis of always pressing the left response key ("1") throughout the experiment, so the following analysis are based on N=44. Table 2 displays the descriptive statistics obtained for the individual experimental blocks as well as across all blocks. As obvious from Table 2 as well, response times were on average longer than in Experiment 1a, as confirmed by a statistical comparison of the two sets of latency data from both experiments, $t(75.12) = -9.42$, $p < .001$. This is consistent with the literature on markedness (Hamilton & Deese, 1971; Schriefers, 1990). Assuming that asking for the *non*-dominant element in a pair is effectively tapping into a reasoning process at the marked end of the dimension, with markedness implying a negation of the affirmative concept, and in the light of related findings that negated terms evoke longer latencies than affirmative terms (Kaup & Zwaan, 2003; Lea & Mulligan, 2002; MacDonald & Just, 1989; Sanford et al., 1996) this result is not surprising.

A one-sample *t*-test was conducted to find that there was no significant difference between the average number of left key presses across the four blocks and the fixed parameter of 40 (expected value under random selection for the four product category blocks, $M = 40.25$, SD = 3.95, $t(43) = .42$, $p = .677$, $d = .06$). Participants, on average, did not indicate the product displayed on the right side of the screen to be least in magnitude with respect to the comparator as responses were at chance level. Again, all product categories were tested separately for any bias, but none was found (for all four *t*-tests, *p*'s were equal to, or larger than, .41). These results led to a rejection of H_{1_1} as formulated for the present experiment (see above).

A repeated measures ANOVA implied that again, the results did not significantly differ between the four product-categories, $F(3, 129) = .19$, $p = .901$. We calculated the Bayes Factor (as above) to test the

Table 2. Experiment 1b, descriptive statistics of left key presses and response times obtained for comparator words in conjunction with "least" (indication of non-dominant target) in addition to Bayes factors and respective classifications according to Jeffreys (1961) in the UK (Cardiff). *N*=44.

	Left key presses		Response times (msec)			
Block	*M*	SD	*M*	SD	BF_{10}	Classification
Essential Oil (comparator: "potent")	10.16	1.28	2073.66	792.02	0.23	Moderate evidence for H_0
Incense Sticks (comparator: "refreshing")	10.11	1.74	2142.00	727.74	0.18	Moderate evidence for H_0
Reed Diffuser (comparator: "powerful")	10.05	1.79	2351.00	824.40	0.17	Moderate evidence for H_0
Scented Candle (comparator: "warming")	9.93	1.65	1915.70	769.13	0.17	Moderate evidence for H_0
All blocks	10.06	.99	2120.59	588.172	0.18	Moderate evidence for H_0
Total presses	40.25	3.95				

evidence in support of our data occurring under the null hypothesis. Across all blocks, the estimated Bayes factor $BF_{10} = .18$, suggested that the observed data were almost five times more likely to have occurred under H_0 than under H_1. This estimation can be interpreted as moderate evidence in favour of the null hypothesis (Jeffreys, 1961). This interpretation also applied for each experimental block, separately. Table 2 displays the Bayes factors for each individual experimental block as well as across all blocks. When eliciting judgments on our product comparisons at the marked end of the dimension, there seems to be no bias that could be attributed to a spatial process.

Experiment 2: replication on a right-to-left background

Spatial primacy information, as we suggest, is rooted in RWD within a given cultural background. We replicated Experiments 1a and 1b within a single experiment, using a sample with a Farsi background (left-to-right). Predictions are symmetric. When asking a positive comparator (X) in view of two similar, unfamiliar products (e.g. "Which product is MOST X?"), Participants in Iran should preferably select the right-positioned product (H_1). When asked "Which of the two products is LEAST X?", Participants should preferably select the left-positioned product (H_{1_1}). On the other hand, if spatial primacy information was not used, participants should select randomly (H_0) throughout.

Method

The present study received ethics approval from the Ethics committee of the Psychology Department of Shiraz University, Shiraz, Iran.

Participants

Because of their academic backgrounds and aspirations, Iranian student participants at university would have had varied, but certainly considerable, exposure to Western international literature and websites for which knowledge in the left–to-right RWD would be either a precondition or would accrue over time with practice. For this reason, the student population cannot count as being purely of a right-to-left RWD background. Therefore, participant samples were drawn in rural areas, from villages around Shiraz. All selected participants were literate, but exclusively in Farsi. They did not have exposure to left-to-right RWD. All in all, the recruitment of participants with this exclusion criterion in place, was not easy to accomplish, so the sample sizes are smaller in this experiment, as compared to Experiment 1. The mean age is also higher than in Experiment 1.

36 participants were recruited in total (25 female, mean age: 49.7 years). Participants were allocated to one of two experimental groups in a quasi-random way, that is, allocating incoming participants such that after any four participants had been allocated to one condition, the next four were allocated to the second condition. One condition focused the test question on the dominant element in a pair ("MOST" instruction, see Experiment 1), whereas the second group focused on the non-dominant element ("LEAST" instruction, see Experiment 1).

Materials and procedure

All materials and procedures were the same as used in Experiment 1a ("MOST" group) and Experiment 1b ("LEAST" group), except that all instructions and written materials had been translated into Farsi.

Results and discussion

Two participants had to be excluded because of inconsistent allocation to experimental groups (they had erroneously received a mixture of "MOST" and "LEAST"), another participant (from the "MOST" group) had to be excluded because only two of the four experimental blocks were completed. This meant, effectively, for the two groups, $N_{most} = 14$ and $N_{least} = 19$.

Parallel to the analyses conducted for Experiment 1, a one-sample t-test was run for both groups separately on the average number of left key presses across all four blocks against 40, in order to determine whether there was a statistically significant tendency to select the product displayed on either side. For the "MOST" group, "left"-responses were less often selected than expected by chance, $M = 32.21$, SD = 7.47, $t(13) = -3.90$, $p = .002$, $d = 1.04$. Participants generally considered the product displayed on the right side of the screen as of greater magnitude with respect to the comparator than the one displayed on the left side, supporting the alternative hypothesis. For each block separately, the number of "left" responses out of 20 trials was compared to the chance value of 10, using one-sample t-tests. Results were as follows: Left key presses for Essential oil (comparator: "potent"): $t(13) = -3.19$, $p = .007$, $d = .85$; left key presses for Incense sticks (comparator: "refreshing"): $t(13) = -3.22$, $p = .007$, $d = .86$; left key presses for Reed diffuser (comparator: "powerful"): $t(13) = -3.98$, $p = .002$, $d = 1.06$; and left key presses for Scented candle (comparator: "warming"): $t(13) = -2.86$, $p < .01$, $d = .76$. Results indicated that the number of left key presses was smaller than the chance level of 10 within each block. A repeated measures ANOVA within the "MOST" group determined that there was no statistically significant difference in number of left presses between the four blocks, $F(3, 39) = 1.14$, $p = .35$, suggesting that the results did not vary across product type categories. The Bayes factors across all experimental blocks in this group was $BF_{10} = 23.35$, suggesting strong evidence for H_1, see Table 3.

The correspondent overall one-sample t-test in the "LEAST" group revealed a non-significant difference between the average number of left key presses across the four blocks and the fixed parameter of 40 ($M = 40.84$, SD = 7.14), $t(18) = .51$, $p = .614$, $d = .12$. In contrast to the "MOST"-condition, results thus indicated that participants selected the product to be least in feature magnitude more or less randomly, rejecting the alternative hypothesis H_{1_1}. In the "LEAST" group, there was no significant deviation from random key selection in any particular product category separately (all p's larger than .54 except for Essential oils, $p = .13$). Neither were there any significant differences between product categories, in terms of a Greenhouse-Geisser-corrected ANOVA on the number of left key presses, $F(2.07, 37.25) = .85$, $p = .44$. The Bayes factors across all experimental blocks in this group was $BF_{10} = .27$, suggesting moderate evidence for H_0, see Table 3.

Descriptive statistics obtained for the individual experimental blocks as well as across all blocks, separated by condition, are displayed in Table 3. As can be seen from Table 2, response times appeared to be slightly longer in the "LEAST" group than in the "MOST" group, as expected from Experiment 1 and the markedness argument, but this tendency was not statistically significant, $t(31) = -.59$, $p = .56$.

Analysing the key presses between the two groups, we compared overall "left"-responses made and found a significant difference, $M_{most} = 32.21$, $M_{least} = 40.84$, $t(31) = -3.36$, $p = .002$. When asked to indicate the dominant element in a pair, participants chose the left one less often than when indicating the non-dominant element.

Conclusively, we found that participants raised and trained exclusively with right-to-left RWD had a tendency to select the right of two items when making judgments in a situation in which discrimination between fictitious products was difficult and could not be based on obvious diagnostic cues.

General discussion

UK participants exhibited a medium-sized effect of preferably selecting the left of two similar products, whereas participants in Iran tended to prefer the right one, when asked to indicate the *dominant* one ("MOST X"). Indicating the *non-dominant* one ("LEAST X"), participants in both countries showed no bias (see Figure 2). This pattern indicates an attribution of spatial primacy to the magnitude as seen in a given object quality. Earlier studies suggest that such attributions might indeed happen. Englund and Hellström (2013), using a word-valence-rating task, found a left-preference bias (or, first-read-bias) in the positive case, reverting to right-preference in the negative case. The difference to our paradigm is that subject-object sentences were used as stimuli. The authors argue that whatever stimulus happens to be the sentence subject receives most weight in the decision, as compared to the sentence object. Thus, their effect may be syntactic/linguistic rather than spatial.

For drawings with a left- or rightward directionality (e.g. body orientation), participants have been

Table 3. Experiment 2, descriptive statistics of left key presses and response times obtained for comparator words in conjunction with "most" (N = 14) and "least" (N = 19) in Iran (Shiraz).

		Left key presses		Response times (msec)			
Condition	Block	*M*	SD	*M*	SD	BF_{10}	Classification
Most	Essential Oil (comparator: "potent")	7.93	2.43	1468.06	769.34	7.48	Moderate evidence for H_1
	Incense Sticks (comparator: "refreshing")	7.57	2.82	1788.33	1085.50	7.91	Moderate evidence for H_1
	Reed Diffuser (comparator: "powerful")	8.14	1.75	2696.89	2832.01	26.48	Strong evidence for H_1
	Scented Candle (comparator: "warming")	8.57	1.87	2377.42	1776.73	4.47	Moderate evidence for H_1
	All blocks	8.05	1.87	2082.68	903.53	23.35	Strong evidence for H_1
	Total presses	32.21	7.47				
Least	Essential Oil (comparator: "potent")	10.79	2.18	1491.17	1171.26	0.68	Anecdotal evidence for H_0
	Incense Sticks (comparator: "refreshing")	10.42	2.91	4057.75	6623.48	0.28	Moderate evidence for H_0
	Reed Diffuser (comparator: "powerful")	9.89	3.25	1726.85	971.36	0.24	Moderate evidence for H_0
	Scented Candle (comparator: "warming")	9.74	2.16	2346.89	2405.85	0.27	Moderate evidence for H_0
	All blocks	10.21	1.79	2405.66	1905.58	0.27	Moderate evidence for H_0
	Total presses	40.84	7.14				

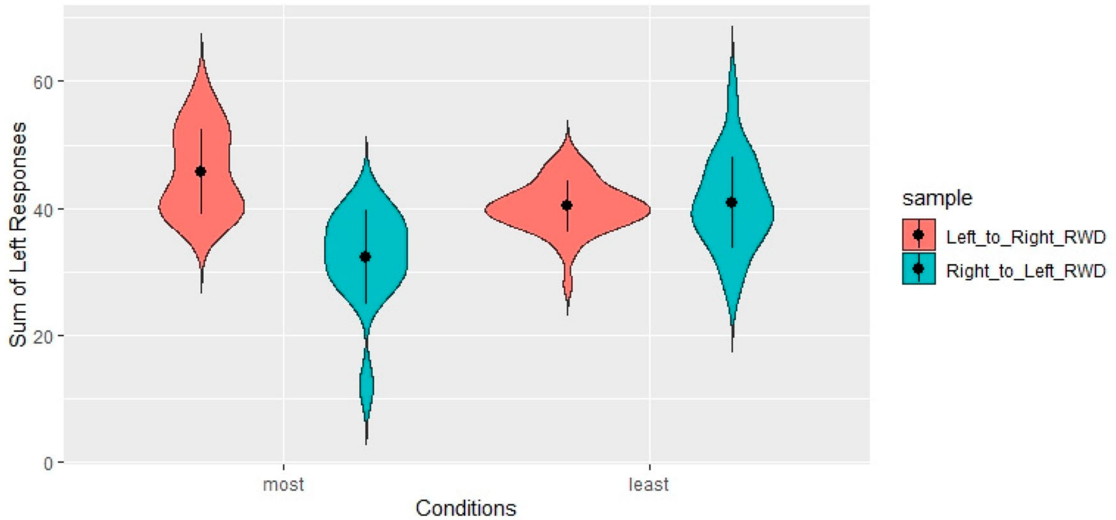

Figure 2. Violin plot of the data distributions for both conditions ("MOST" and "LEAST") in the two countries (UK: Left-to-right RWD, and Iran: Right-to-left RWD). The Y-axis refers to the number of left-choices across all four blocks. The expected value for this is 40 under random selection.

found to prefer RWD-congruent directionalities (Chokron & De Agostini, 2000; Ishii et al., 2011; Loffing et al., 2017). Participants probably transfer RWD-based spatial primacy information into judgments about a quality of the object. Notably, the stimuli carried left- or rightward directionality *within themselves*, whereas the present project is interested in *pairs of objects* with *no inbuilt directionality*.

We submit that spatial primacy, in terms of object location within a display, can convey information relevant to the attribution of magnitudes in feature objects. Spatial primacy *blends* with dimensional dominance (Casasanto, 2009; von Hecker et al., 2016, 2019, 2020), such that an object that has "*more*" of a quality can be mentally represented as positioned closer to the RWD origin. Blending in mental space means that RWD determines a directional representation (akin to an action hierarchy), according to which whatever "comes first" will be attributed "more" of the quality. The reversal of patterns between the UK and Iran suggests spatial grounding by virtue of the learned RWD. As RWD can underly reasoning and decision-making with ordered mental representations, our argument is close to the spatial grounding assumption for the number line (e.g. Dehaene et al., 1993; Gevers et al., 2006; Ito & Hatta, 2004)[2].

[2]The interpretation of results relating to the number line, on the surface, may look contradictory to our assumptions, as for example in the West, small numerical magnitudes are thought to be associated with left space and larger numerical magnitudes with right space. Therefore, one might

Regarding the bimodality of the distributions of left key responses (see Figure 2), some participants might have deliberately "recognised" there being no diagnostic information, thus responding at random. Other participants might have used spatial information (resulting in spatial bias). Looking into individual differences with regards to strategies used is beyond the scope of the present paper, but is of further interest.

Casasanto's (2009) research poses an alternative prediction, as by his approach, horizontal space can also serve as metaphorical projection of a valence dimension, such that, on the grounds of handedness, *right* is associated with *good*, and *left* with *bad*. Following this logic, and as most of our product features were positive in valence, we should expect results contrary to the ours, in the MOST condition: In Cardiff, products displayed on the *right* should be perceived as possessing more of the good quality than those on the left, whereas the Shiraz results would fit the valence-based prediction. In terms of the LEAST condition however, neither sample's data support an explanation via a horizontal valence dimension: In this case one predicts a uniform left-bias for the products in Cardiff as well as in Shiraz, which is not what we found.

Is it "mere primacy" (without blending)?

We propose that primacy is *blended* with dominance in terms of a dimensional magnitude. Alternatively, the preference observed here could be merely due to an automatic link between sequential primacy and an elevated salience of the stimulus perceived first. However, findings on laterality and preference often pertain to specific consumer-relevant situations with co-determining factors (Biswas et al., 2014; Chae & Hoegg, 2013; Deng & Kahn, 2009; Romero & Biswas, 2016; Valenzuela & Raghubir, 2009). The simple design used here addresses the role of RWD-induced spatial primacy more rigorously.

Second, if primacy was the exclusive factor, "LEAST" and "MOST" should yield identical patterns: Participants would preferably choose the element closest to RWD origin. This was not the case, as an asymmetric pattern resulted. We therefore submit *metaphoric blending* as crucial factor: Primacy may be blended with mental simulation of a *positive magnitude* of an attribute, but may not well be blended with mental simulation of a *lack thereof* (Casasanto, 2009; von Hecker et al., 2016, 2019; von Hecker & Klauer, 2020), explaining the asymmetrical finding between the "MOST" and "LEAST" conditions as observed in UK and Iran.

Third, if primacy was mapped onto grammatical comparison, "MOST" as much as "LEAST" should be placed close to the origin of the spatial dimension, as both expressions are grammatical superlatives. However, in contrast, primacy appears to be related to the *meaning* of the magnitude in question. The finding that spatial biases occur in the "MOST" condition but not in the "LEAST" condition suggests that an element identified as "MOST" dominates the other one in mental simulation just because that element's spatial primacy is blended with magnitude.

Asymmetric results in the light of linguistic markedness

Response generation under "MOST X" versus "LEAST X" instructions yielded symmetrical effect vs. no-effect patterns in both countries. Based on the literature on linguistic markedness (Hamilton & Deese, 1971) one may attempt to interpret the results in two possible ways. First, as just a re-statement of the often-reported greater unreliability of making a judgment at the marked than at the unmarked dimensional end (Schriefers, 1990; Schubert, 2005; van der Schoot et al., 2009), one may predict not only longer response latencies in the marked than in the unmarked case, but also a greater proportion of (error) variance associated with the slowing. On the other hand, to the extent that responses at the marked end imply some sort of negation of the dimensional semantics ("reversal" of the meaning), one might stipulate a more reliable difference in the process that leads to response generation, that is, on the basis of the literature on negation and attentional focus (Kaup & Zwaan,

predict for the present paradigm that the right side (not the left one) should be judged as having most of a property. However, in our view, the semantics of the number line are best described by "counting." As for example in Western backgrounds the reading/writing schema implies, an action starting from the left and proceeding towards the right, this action means counting upwards in discrete units, starting with "1". This number represents the beginning and therefore highest dominance, as the counting starts with it. We argue further that the second action in the counting sequence, "2", is dominated by "1" and itself dominates "3", as one goes along the counting dimension. This means that although the denoted magnitudes of the counted numbers increase from left to right, their primacies continually decrease, as each step that comes before another one always has higher primacy in the action sequence.

2003; Lea & Mulligan, 2001; MacDonald & Just, 1989; Sanford et al., 1996). In this case, responses at the marked end should *not* contain more error than those at the unmarked end. Inspecting the data in Tables 1–3 gives eyeball support for the latter explanation in the UK (proportion of SD versus $M = .35$ for "MOST", and .27 for "LEAST"), and for the former explanation in Iran (proportion of SD versus $M = .43$ for "MOST", and .79 for "LEAST"). In our earlier research we directly compared processing at the unmarked and the marked end of a number of different order dimensions (von Hecker et al., 2016) and found clear spatial primacy effects for "unmarked", but no effects for "marked". Likewise Schubert (2005) in his work on power and verticality found still significant, but much smaller effects when participants were asked to indicate the "less powerful" concept (marked end) in a vertical display of two concepts, compared with the instruction to indicate the "more powerful" concept (unmarked end). The similarity in the asymmetric pattern observed in the present data between UK and Iran leads us to believe that there are systematic differences in the way our participants processed their judgments at the unmarked and the marked end of the quality dimensions. However, the current data do not yet allow for the conclusion that it is indeed markedness that distinguishes the "most" and the "least" condition. To this end, it would be informative to vary markedness and dominance orthogonally (preferably with adjectives without morphological marking, e.g. most warm vs. least warm vs. most cold vs. least cold)[3]. These differences need to be further explored in future research.

Alternative explanation: polarity correspondence?

The concept of polarity correspondence (Lakens, 2012; Proctor & Cho, 2006) makes use of markedness as auxiliary construct, since the idea is here that the unmarked end of a dimension be "plus-coded" whereas the marked end be "minus-coded". Another assumption is that responses also are "plus"-and "minus" coded, namely, a response on the right side "plus" and a response on the left side "minus". Within this approach, spatial mapping effects occur as a result of congruence, or incongruence, between stimulus-code and response-code. It is difficult to explain our present results with these assumptions. We would have to assume that the unmarked pole for the stimulus dimension (via primacy through RWD) is *left* in the Cardiff sample, and *right* in the Shiraz sample. That being the case, and as the response dimension is "plus"-poled on the right side, at least for right-handers (Proctor & Cho, 2006), one would have to predict a facilitation effect for the right side through correspondence between stimulus- and response-code in Shiraz, but no facilitation in Cardiff, as these codes would not correspond. The present results are therefore easier explained by assuming that RWD-based primacy is influencing responses without any particular codes on the response-side.

Conclusion

In conclusion, we submit that the spatial positioning of an object or entity within a horizontal display may contribute information relevant to one's appreciation of that entity relative to others within the same display. This presumably occurs via automatic, highly overlearned primacy implications as derived from RWD. Whilst this research still has to be extended to see whether similar effects are in fact obtainable in the social domain (e.g. with pictures of faces, or more dynamic materials involving target persons), the present findings imply the possibility that spatial primacy may trigger perceptions of product qualities and quantities in relation to stimulus features in general that are otherwise not obvious, that is, are not part of the explicit stimulus presentation. According to the present findings, the exact way how spatial factors exert this kind of influence should be examined with reference to the particular cultural background in which, for example, a product advertisement campaign is being launched (see Ploom et al., 2020). It is important to stress again that, similar to the argument made by Winkielman and Cacioppo (2001) about mental fluency, we do not believe that spatial primacy would usually act in the foreground. In most everyday situations relating to ranking, ordering, or making decisions about priority and preference, there exist stable, pre-existing cues and features that will trigger these decisions. But as demonstrated in the present research, lack of sufficient information and a simultaneous

[3]We thank one of the Reviewers for making us aware of this issue and for suggesting the possible approach to its solution.

commitment to making a response may create a situation in which spatial primacy will have its effect.

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