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Empirical Article

Strong versus weak embodiment: Spatial iconicity in physical, abstract, and social semantic categories

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Background
Perceptual and action systems seem to be related to complex cognitive processes, but the scope of grounded or embodied cognition has been questioned. Zwaan and Yaxley (2003) proposed that cognitive processes of making semantic relatedness judgments can be facilitated when word pairs are presented in ways that their referents maintain their iconic configuration rather than their reverse-iconic configuration (the spatial iconicity effect). This effect has been observed in different semantic categories using specific experiments, but it is known that embodiment is highly dependent on task demands.
Method
The present study analyzed the spatial iconicity effect in three semantic categories (physical, abstract, and social) using the same experimental criteria to determine the scope of embodied cognition. In this reaction-time experiment, 75 participants judged the semantic relatedness of 384 word pairs whose experimental items were presented in their iconic or reverse-iconic configurations.
Results
Two mixed-effects models with crossed random effects revealed that the interaction between word meaning and spatial position was present only for physical concepts but neither for abstract nor social concepts.
Conclusions
Within the framework of strong and weak embodiment theories, the data support weak embodiment theory as the most explicative one.

Key words: Spatial iconicity, embodied cognition, abstract concept, physical concept, social concept.

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INTRODUCTION

In recent decades, the study of the influence of embodied mental representations in cognition has been a fruitful field of research, especially since the Zwaan and Yaxley (2003) seminal study. These authors conducted an experimental procedure in which word pairs were presented both vertically and horizontally and subjects were asked to judge their semantic relatedness. Cognitive processing of semantic relatedness judgments was facilitated when word pairs were presented in their iconic configuration (i.e., in their position on the axis that matched the one in the physical world) as opposed to their reverse-iconic configuration. This was called the "iconicity effect," which was defined as the facilitation of judgment about the semantic relatedness of word pairs presented in their spatial iconicity form. The spatial iconicity effect has been observed by several authors (e.g., Berndt, Dudschig, Miller & Kaup, 2019; Dudschig, Lachmair, de la Vega, De Filippis & Kaup, 2012; Dudschig, Souman, Lachmair, de la Vega & Kaup, 2013; Estes, Verges & Barsalou, 2008; Ostarek & Vigliocco, 2017; Šetić & Domijan, 2007). These results have been interpreted as the influence of grounded or embodied mental representations in cognition. Therefore, although it is a widely applied experimental paradigm, word pairs commonly used in these studies are concrete concepts about the physical world (such as objects or animals). For example, the concepts "hat" and "head" usually match a vertical position in the physical world. These kinds of mental representations are supposed to influence our conceptual processing. For instance, other studies, such as the one conducted by Pecher, van Dantzig, Boot, Zanolie, and Huber (2010), showed that semantic decision tasks direct spatial attention by performing mental simulation and facilitating the processing of targets in task-congruent locations.

The previous findings have also been observed in abstract (Bardolph & Coulson, 2014; Casasanto, 2009) and social concepts (also known as *power hierarchy* concepts; Gagnon, Brunye, Robin, Mahoney & Taylor, 2011; Lu, Schubert & Zhu, 2017). As an illustration, "growth" and "reduction" or "captain" and "soldier" could be considered as examples of abstract and social concepts, respectively. Regarding the abstract category, there is not a clear consensus about which type of concepts should be considered. In this sense, Borghi *et al.* (2017) describe some of the variability in the abstract stimuli used in the literature in the field. While perceptual and action systems seem to be related to complex cognitive processes such as conceptual knowledge or comprehension, the relative importance of grounded or embodied cognition in abstract concepts has been questioned (Mahon & Caramazza, 2008; Pecher, Boot & van Dantzig, 2011; Pulvermüller, 2013). Thus, there have been some concerns about the generalizability of these results (Machery, 2007).

According to recent theories of cognition, conceptual processing is highly influenced by its situated simulations, which implies that simulating concepts prepares individuals for action and/or perception (Barsalou, 2008). In conceptual knowledge, many embodiment theories advocate for non-specific mechanisms that relate different modalities of semantics (i.e., Barsalou, 2008; de Vega, Glenberg & Graesser, 2012; Glenberg & Gallese, 2012; Meteyard, Rodriguez-Cuadrado, Bahrami & Vigliocco, 2012; Wang, Jiang, Feng & Lu, 2020). Although this theoretical perspective has been criticized (i.e., Clark, 2008; Goldinger, Papesh, Barnhart, Hansen & Hout, 2016), grounded or embodied experiences have been proposed as relevant factors in cognitive processing to construct meaning (Coello & Fischer, 2016; Fischer & Coello, 2016; Zwaan, 2014, 2016; Louwerse, 2011, 2018).

Thus, it is noteworthy that a variety of different predictions exist from various embodiment proposals in the scientific literature depending on the given importance of embodiment for cognition. While the general theoretical perspective of embodiment allowed psychologists to move beyond classical philosophical tendencies, it is necessary to analyze the capacity of the different proposals to explain embodied cognition and its effects in conceptual processing. Purely embodied theories postulate that (1) semantics are not constructed only by means of action and perception, (2) the functional interactions among action, perception, and semantics require meaning to be influenced by all these systems, (3) meaning without embodiment is incomplete, (4) embodied cognition facilitates the integration of multimodal information, and (5) both concrete and abstract concepts can be explained by embodied cognition (see, e.g., the integrative proposals of Pulvermüller, 2013). On the contrary, less radical perspectives have been proposed that allow some parts of semantics, such as concepts, to be represented at a symbolic level with less influence of action and perception (e.g., Mahon, 2015a, 2015b; Mahon & Caramazza, 2008; Pulvermüller, 2013). Furthermore, connections between symbols and their representations could be purely symbolic, but they could also be functionally connected to action and perception systems. The most radical embodied cognition perspectives are considered *strong* embodiment theories, while the less radical embodied perspectives are considered *weak* embodiment theories. Strong embodiment theories predict a large effect of spatial representations on conceptual processing, while weak embodiment theories predict less important spatial representation effects.

On the one hand, in the scientific literature, a large number of empirical studies have suggested that spatial representations substantively influence semantic processes due to their considerable importance within mental representations (e.g., Coello & Fischer, 2016; Fischer & Coello, 2016). On the other hand, it is noteworthy that considerably idiosyncratic experimental designs have been used to obtain positive results in favor of embodiment theories. Along this line, these effects can be observed only under certain specific experimental conditions, without showing any possibility of generalization to other conditions or stimuli. Some examples of specific experimental designs in favor of those effects can be found in Ostarek and Vigliocco (2017) using images as stimuli; in Meteyard, Bahrami, and Vigliocco (2007) using motion-detection tasks within standard psychophysics; or in Dunn, Kamide, and Scheepers (2014) using different presentation modalities and eye-movement measures to test the effects found in Dudschig, Souman, Lachmair, de la Vega, and Kaup (2013). These previous findings are relevant and show evidence in favor of embodiment, but applying heterogeneous experimental designs. Given that conceptual processing is highly dependent on task demands, theoretical predictions should be evaluated within a specific task to assess their validity when conceptual knowledge is used as a level of analysis (Mahon & Hickok, 2016). Thus, it is necessary to analyze the influence of embodied cognition on conceptual processing using widely applied experimental paradigms whose results should be comparable across different semantic categories, since, to our knowledge, the effect has not been tested yet using physical, abstract, and social semantic categories within the same experiment.

In this way, Mahon (2015a, 2015b) offered the criticism that published studies in favor of the embodied cognition hypotheses often concluded that cognition is embodied without considering alternative non-embodied explanations. Despite the usual embodiment theories, Mahon and Caramazza (2008; see also Pulvermüller, 2013) argued that the co-activation of sensory and motor systems during conceptual processing could have been wrongly interpreted as the embodiment of concepts. For example, see the domain-specific sensory-motor hypothesis (Mahon & Caramazza, 2008) or the action perception theory (Pulvermüller, 2013). The former postulates that concepts are organized and represented depending on their own use. The latter proposes different neurobiological mechanisms, such as *neural cell assemblies*, that differentially contribute to specific facets of meaning and concepts. According to these perspectives, two representations, such as the concept "hat" and the sensory-motor information required to use hats, would be represented in different *sets of nodes* but would be connected.

Thus, the present study was focused on the differential effects predicted by both the strong and weak embodiment theories when three types of semantic categories are processed (i.e., physical, abstract, and social). Given that the spatial iconicity effect has been observed in all three semantic categories included in the present study, if strong embodiment theories are predominant, then spatial iconicity should be observed with a similar effect in all semantic categories, applying the same experimental conditions. Otherwise, if weak embodiment theories are predominant, then a differential spatial iconicity effect dependent on semantic categories would be observed, such as the different hypotheses would predict. Consequently, the aim of the present study was to analyze to what extent grounded or embodied cognition differentially affects word-pair processing from different semantic categories, that is, to partially answer the *scope problem*, because some of the findings of previous experiments have not generalized to broader domains of conceptual processing (Machery, 2007). It is worthy to mention that this experiment was focused only on the spatial iconicity effect but that embodiment theories have richer and more complex empirical foundations than this effect. Complementarily, the predictions of both strong and weak embodiment theories were tested using a propitious a priori experimental design for all the semantic categories considered in the present study. To determine the influence of grounding cognition or embodiment, a within-subjects design was conducted following the experimental criteria of Zwaan and Yaxley (2003) in each semantic category. Reaction Times (RTs) were recorded as the processing time needed to judge the semantic relatedness of word pairs.

METHOD

Participants

Seventy-five undergraduate students (59 women; age: $M = 22.9 \pm 1.2$ years) from Universidad Autónoma de Madrid took part in this study. The study was carried out in individual sessions with a mean duration of 20 min at the Department of Psychology lab. The students received a credit for their participation. When participants expressed interest in the research, they were sent an information sheet with more details about the study. It was made clear to each participant that their information would remain confidential and that they could withdraw from the study at any time, up until the data analysis was completed. Before the experiment was conducted, participants provided written informed consent. The data from five participants were deleted because they failed more than 25% of the trials.

Materials

The study used 384 word pairs, presenting each stimulus pair in its iconic and reverse-iconic configurations. Three different experimental categories were used: physical, abstract, and social concepts. The control conditions were conducted using word pairs with both semantic relations (i.e., without spatial relation) and control (i.e., without spatial relation or semantic relation) concepts. Experimental and control word pairs were established using latent semantic analysis (LSA; Landauer, McNamara, Dennis & Kintsch, 2007) to measure the words' semantic similarity (this is a computational measure used to evaluate semantic relatedness of words) using the LEXESP (Sebastián, Martí, Carreiras & Cuetos, 2000) as the linguistic corpus. Mean cosine-based similarity was 0.42 for physical, 0.30 for abstract, 0.30 for social, 0.40 for semantic relation, and 0.06 for control word pairs. A minimal cosine of 0.25 was established for word pairs in all related categories, and word pairs were selected for the control category when their cosine was lower than 0.10.

A total of 192 experimental and 192 control word pairs were used. Sixty-four physical word pairs were established using the item pool from Zwaan and Yaxley (2003) (but only 25 of their word pairs obtained cosine similarities over 0.25 in Spanish, so the rest of the word pairs were carefully chosen by the researchers). Another 64 word pairs were established for both abstract and social categories. For control word pairs, 64 were used as semantic relation (i.e., without spatial relation) and 128 were used as control (i.e., without spatial relation and without semantic relation) categories. Different exemplars for both experimental and control word pairs can be seen in Table 1. The items presentation order was counterbalanced, but only one form of presentation was used per word pair (i.e., only the iconic or the reverse-iconic presentation of each word pair was presented for each participant).

Procedure

A complete within-subjects experimental design was conducted in which participants received instructions to judge the semantic relatedness of word pairs. Word pairs were presented on a computer screen under the control of *E-Prime 1.2* in capital letters during individual sessions with a mean duration of 20 min. All participants responded to the 384 word pairs, which were randomly ordered for each of them. The procedure, like that of Zwaan and Yaxley (2003), consisted of the presentation of a fixation cross for 250 ms to control the location of eye fixations, after which word pairs appeared vertically or horizontally. Participants were informed about vertical and horizontal presentation of word pairs in advance, and they were also told to indicate whether they were semantically related or not, pressing a "yes" or "no" key, as soon as possible. RTs, correct answers, and errors were registered for all experimental categories. See both experimental and control word-pair exemplars in Fig. 1.

Data analysis

Before analyzing the data, trials with RTs less than 550 ms were deleted. Also, trials (n) whose RTs were longer than 2000 ms and their following trials ($n + 1$) were not included in the analysis to avoid attentional bias. Thirty-three items were excluded from the analysis because they were not correctly answered at least 75% of the times they were presented.

The data were analyzed with linear mixed-effects models with crossed random effects using the *lm4* package (version lme4_1.1-13; Bates, Maechler, Bolker & Walker, 2015) in R statistical software (version 4.0.4; R Core Team, 2021). Two different models were fitted for the error rates and for the reaction times. The error rates were modeled with a generalized linear mixed-effects model using a binomial distribution with logit link to analyze the error rates. In both models, Presentation (horizontal vs. vertical), Congruency (congruent vs. incongruent), and Category (control vs. semantic relation vs. physical vs. abstract vs. social conditions) were entered as fixed effects in the models.

To select the most appropriate random structure for the data, a bottom-up model selection strategy was followed (Martínez-Huertas, Olmos & Ferrer, 2022; Matuschek, Kliegl, Vasishth, Baayen & Bates, 2017). The procedure, as described in Martínez-Huertas, Olmos, and Ferrer (2022), consists of the sequential comparison of different random structures using Chi-square tests. Specifically, we compared four random structures for the mixed-effects model with crossed random effects: random intercepts for participants and for items, random intercepts and slopes for participants and random intercepts for items, random intercepts for participants and

Table 1. *Ten word-pair exemplars per experimental condition*

Experimental word pairs						Control word pairs			
Physical		Abstract		Social		Semantic relation		Control	
Plane	Runway	Maximum	Minimum	Businessman	Worker	Chocolate	Candy	Elephant	Streetcar
Penthouse	Basement	Victory	Defeat	King	Count	Coffee	Milk	Fan	Satellite
Roof	House	Expensive	Cheap	Captain	Soldier	Lettuce	Tomato	Clown	Stamp
Car	Road	Confidence	Insecurity	Pope	Priest	Goat	Sheep	Skull	Cherry
Fortress	Moat	Virtue	Default	Teacher	Disciple	Carnation	Rose	Mask	Kite
Ceiling	Flat	Rise	Fall	Coach	Athlete	Gorilla	Chimpanzee	Squid	Amulet
Curtain	Stage	Abundance	Absence	Executive	Employee	Wire	Rope	Button	Donkey
Rider	Horse	Growth	Reduction	Queen	Princess	Aluminum	Bronze	Squirrel	Wallet
Knee	Ankle	Winner	Loser	Champion	Finalist	Tank	Bomb	Pony	Star
Lighthouse	Coast	Luxury	Misery	Judge	Prosecutor	Lead	Iron	Galaxy	Rag

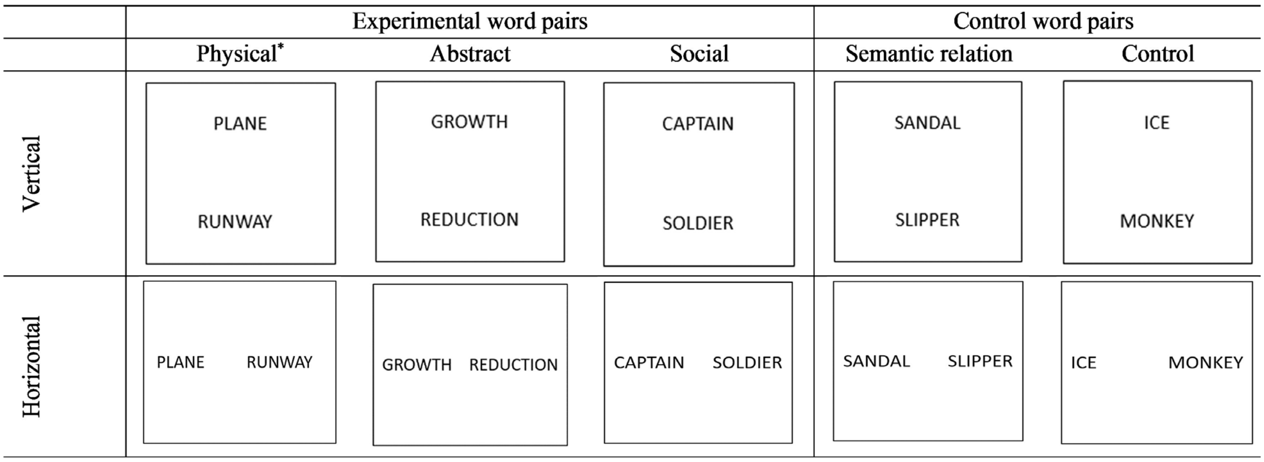

Fig. 1. Experimental and control word-pair exemplars. *Note*: *Word pairs that were similar to those of Zwaan & Yaxley (2003). Word pairs were presented in Spanish.

random intercepts and slopes for items, and random intercepts and slopes for participants and random intercepts and slopes for items. As shown below, the data supported a mixed-effects model with random intercepts and slopes for participants and random intercepts and slopes for items.

RESULTS

First, a generalized mixed-effects model with random intercepts for participants and items was fitted for the error rate to control possible bias of the performance in the different tasks. Results showed that none of the estimated fixed effects were statistically significant, except the intercept (b = 2.99; SE = 0.14; z = 21.81; $p < 0.01$). The mean proportion of correct answers in all the conditions was 0.94 (SD = 0.25).

Second, the most appropriate random structure was selected for the mixed-effects model with crossed random effects using a bottom-up model selection strategy. In a first step, it was found that including random slopes for participants and for items increased the model fit compared with the mixed-effects model with only random intercepts ($\chi^2(27) = 137.41$, $p < 0.01$, and $^2(27) = 99.55$, $p < 0.01$, respectively). In a second step, it was found that the inclusion of random slopes for both participants and items increased the model fit compared with the intermediate models with only one random slope for participants or items ($\chi^2(27) = 98.28$, $p < 0.01$, and $\chi^2(27) = 136.14$, $p < 0.01$, respectively). Thus, a mixed-effects model with both random intercepts and slopes for participants and items was fitted to analyze the experimental effect of the present study.

Third, the selected mixed-effects model with crossed random effects for the reaction times was fitted. Results of this model can be observed in Table 2. A statistically significant third-order interaction effect was observed for only the physical condition (b = 44.63, SE = 19.66, 95% CI [6.10, 83.17], t = 2.27, $p < 0.05$), while both abstract and social semantic categories showed no effects in the reaction times (b = 9.89, SE = 18.75, 95% CI [−26.86, 46.63], t = 0.53, p = 0.60, and b = −18.56, SE = 17.88, 95% CI [−53.60, 16.48], t = −1.04, p = 0.30, respectively).

These results are graphically presented in Fig. 2. As was mentioned above, the only statistically significant third-order interaction effect was related to the difference between congruent and

Table 2. *Estimates of the mixed-effects model with crossed random effects for physical, abstract, and social semantic categories*

Fixed effects	B [95% CI]	*Std. Error*	*t*
Intercept	**1337.25 [1295.52, 1378.99]**	**21.29**	**62.80****
Incongruent	1.57 [−15.29, 18.44]	8.61	0.18
Vertical	−5.64 [−20.70, 9.42]	7.68	−0.73
Semantic relation	**−116.92 [−150.48, −83.35]**	**17.13**	**−6.83****
Physical category	**−102.72 [−135.94, −69.49]**	**16.95**	**−6.06****
Abstract category	**−45.03 [−82.04, -8.03]**	**18.88**	**−2.39***
Social category	**−86.01 [−117.91, −54.11]**	**16.27**	**−5.29****
Incongruent*Vertical	−2.23 [−22.44, 17.99]	10.31	−0.22
Incongruent*Semantic relation	1.92 [−27.73, 31.57]	15.13	0.13
Incongruent*Physical category	−5.25 [−37.27, 26.77]	16.34	−0.32
Incongruent*Abstract category	8.54 [−21.99, 39.06]	15.57	0.55
Incongruent*Social category	10.46 [−18.74, 39.66]	14.90	0.70
Vertical*Semantic relation	6.34 [−19.58, 32.26]	13.23	0.48
Vertical*Physical category	−7.41 [−35.43, 20.60]	14.29	−0.52
Vertical*Abstract category	−18.39 [−45.04, 8.26]	13.60	−1.35
Vertical*Social category	12.60 [−12.81, 38.01]	12.97	0.97
Incongruent*Vertical*Semantic relation	−3.87 [−39.43, 31.70]	18.15	−0.21
Incongruent*Vertical*Physical category	**44.63 [6.10, 83.17]**	**19.66**	**2.27***
Incongruent*Vertical*Abstract category	9.89 [−26.86, 46.63]	18.75	0.53
Incongruent*Vertical*Social category	−18.56 [−53.60, 16.48]	17.88	−1.04
Random effects (variances)			
Error			51242.00
Items: Intercepts			3631.16
Items: Incongruent			2530.34

(continued)

Table 2. (continued)

Random effects (variances)	
Items: Vertical	363.14
Items: Semantic relation	7148.07
Items: Physical category	6239.69
Items: Abstract category	2748.50
Items: Social category	5377.89
Participants: Intercepts	27850.09
Participants: Incongruent	32.43
Participants: Vertical	220.53
Participants: Semantic relation	1827.59
Participants: Physical category	1975.04
Participants: Abstract category	3119.49
Participants: Social category	2123.64
N_{Item}	346
$N_{Participant}$	70

Note: A mixed-effects model with random intercepts and random slopes for both participants and items was conducted using presentation (horizontal vs. vertical), congruency (congruent vs. incongruent), and category (control vs. semantic relation vs. physical vs. conceptual vs. social conditions) as fixed effects. Bold values indicate statistically significant effects ($p < 0.05$) and interval confidence estimates not including zero. Bold values indicate statistically significant effects ($p < 0.05$) * = $p < 0.05$ ** = $p < 0.01$.

incongruent conditions in the physical category when they are presented vertically. In abstract and social semantic categories, only the main effect of category presented statistically significant differences with respect to the control conditions. This means that the embodied cognition effect was found only for the physical category.

DISCUSSION

The spatial iconicity effect that was originally reported by Zwaan and Yaxley (2003) has been supported by a vast quantity of empirical evidence. While this effect has been observed in different variations of the original experiment (e.g., Berndt, Dudschig, Miller & Kaup, 2019; Dudschig, Lachmair, de la Vega, De Filippis & Kaup, 2012; Dudschig, Souman, Lachmair, de la Vega & Kaup, 2013; Estes, Verges & Barsalou, 2008; Ostarek & Vigliocco, 2017; Šetić & Domijan, 2007), we decided to test its capacity in predicting embodiment effects in different semantic categories due to the considerable idiosyncrasy of experimental designs that obtained positive results supporting embodied cognition hypotheses. Thus, the present study analyzed the *scope problem* concerning the generalizability of particular grounded or embodied cognition experiment results (Machery, 2007) applying the same experimental criteria to different semantic categories. Given that conceptual knowledge processing is dependent on task demands, different predictions were postulated to support or oppose the strong and weak embodiment approaches. While the influence of grounded cognition has been proposed as an important mechanism in cognition (e.g., Barsalou, 2008; Mahon & Hickok, 2016), in the present study, only physical word pairs showed the spatial iconicity effect while abstract and social concepts did not.

Given that experimental word pairs were presented in both their iconic and their reverse-iconic configurations, if the strong embodiment proposal were predominant in conceptual processing, then the spatial iconicity effect would be observed in all the evaluated semantic categories (whether physical, social, or abstract). Alternatively, if the weak embodiment view were predominant, then the spatial iconicity effect would appear in those semantic categories more related to the physical world. Some hypotheses, such as the domain-specific sensory-motor one, could explain the differential effects of spatial iconicity in conceptual processing because concepts would be organized and represented depending on their use (Mahon & Caramazza, 2008).

Machery (2007) operationalized the embodiment hypotheses as a way to test whether concepts are qualitatively different from

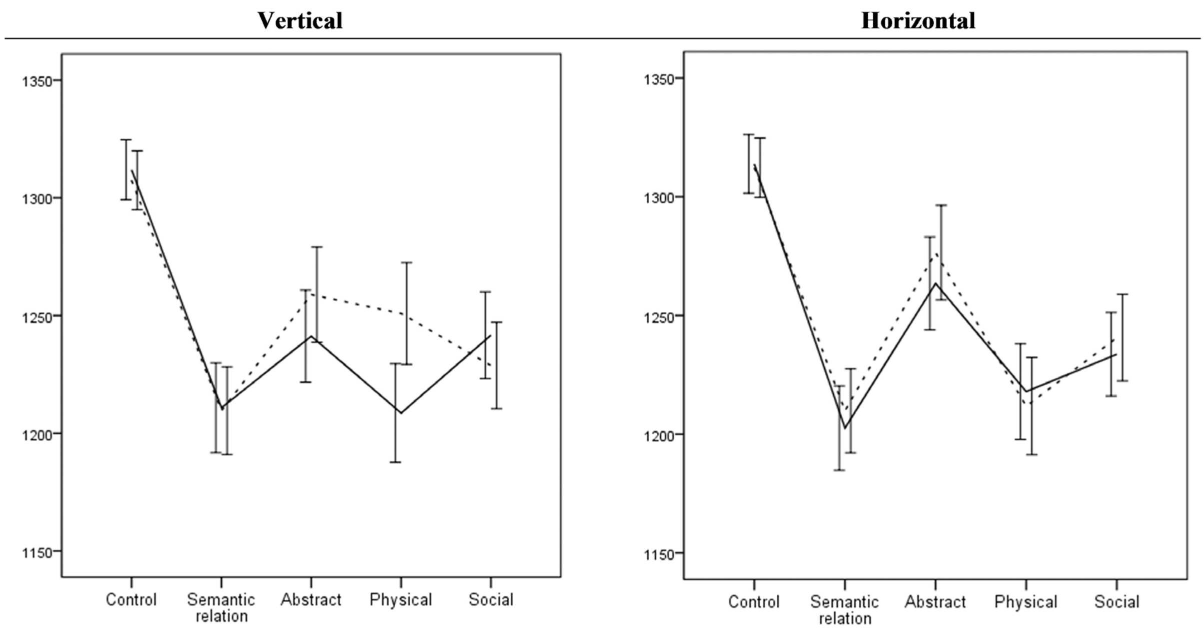

Fig. 2. Mean RTs for presentation (horizontal vs. vertical), congruency (congruent vs. incongruent), and categories of the study (control vs. semantic relation vs. physical vs. conceptual vs. social conditions). *Note*: Continuous lines: congruent conditions. Discontinuous lines: incongruent conditions. y-axes range from 1150 to 1350 ms. 95% confidence intervals are represented in the graph.

percepts, that is, to test whether the influence of knowledge representation affects higher cognitive processes. The *scope problem* has been proposed as a relevant issue in embodied cognition because some tasks elicit the manipulation of perceptual representations, while others do not (Machery, 2007). Hence, it is necessary to understand the influence of embodiment in conceptual knowledge by exploring different item semantic categories under the same experimental conditions. Similar requirements have been proposed by other researchers (e.g., Mahon & Caramazza, 2008; Mahon, 2015a, 2015b).

In the present study, the spatial iconicity effect was observed only for the physical category, while no differences between congruent and incongruent conditions were observed in the vertical presentation of abstract or social semantic categories. No influence of the horizontal presentation (i.e., an irrelevant presentation for the embodiment predictions using these items) was observed in any of the semantic categories. A straightforward conclusion of these results is that the grounding or embodiment perspective has a differential influence over conceptual knowledge processing depending on the semantic category that is being processed. A further conclusion based on these results can be related to the scope of grounded or embodied cognition: there is a wealth of empirical evidence supporting the influence of embodiment in conceptual processing, but positive results have been observed in idiosyncratic experimental tasks (e.g., Dudschig, Souman, Lachmair, de la Vega & Kaup, 2013; Dunn, Kamide & Scheepers, 2014; Meteyard, Bahrami & Vigliocco, 2007; Ostarek & Vigliocco, 2017).

In the present study, a concreteness effect was found. Specifically, statistically significant lower RTs were obtained only for physical, but neither for abstract nor social categories. Previous research has found divergent results for concreteness and abstractness effects that are commonly observed due to facilitation or interference of conceptual processing due to perceptual simulation of concepts (Barber, Otten, Kousta & Vigliocco, 2013; Kousta, Vigliocco, Vinson, Andrews & Del Campo, 2011; Malhi & Buchanan, 2018). Probably, as discussed in Malhi and Buchanan (2018), the task instructions (based on semantic relatedness judgments of word pairs) conditioned the cognitive processes associated with perceptual simulation of concepts for the different semantic categories, which determines the presence of concreteness effects in the present study. The concreteness effect found here would be a result of a facilitation of conceptual processing that could be explained by the congruency between meaning and spatial position only for physical concepts (such as in Šetić & Domijan, 2007). As was expected, shorter RTs were obtained for the more physical concepts compared with the more abstract ones. While different studies have found a statistically significant influence of spatial iconicity in both abstract (Bardolph & Coulson, 2014; Casasanto, 2009) and social concepts (Gagnon, Brunye, Robin, Mahoney & Taylor, 2011; Lu, Schubert & Zhu, 2017), these effects have not been observed in the present study. However, the physical category showed similar results to other studies (Dudschig, Souman, Lachmair, de la Vega & Kaup, 2013; Estes, Verges & Barsalou, 2008; Šetić & Domijan, 2007). Therefore, while physical category concepts would be more universal in terms of their meaning, abstract and social concepts would be more dependent on contexts or situations.

This study is not exempt from limitations. Predictions of embodiment theories seem to be clear when physical concepts are evaluated, but substantial divergences can be observed when more complex concepts are considered. In this sense, following Borghi *et al.* (2017), great variability can be found in the abstract stimuli used in the experimental literature in the field, making it complicated to find any consensus about the content that an abstract stimulus should have. In the present study, we selected abstract word pairs that were related words, but our item selection mostly focused on opposites for the majority of the cases, since other studies have shown statistically significant results for embodied cognition using abstract opposites as "good" and "bad" (e.g., Casasanto, 2009). This limitation could be also extended to other semantic categories like, for example, social concepts. In this sense, our word pair selection for social concepts was focused on social hierarchy (e.g., soldier – captain), similar to other studies such as those of Yang, Nick Reid, Katz, and Li (2021) and Zanolie *et al.* (2012). Hence, this is just a limited selection of abstract and social word pairs, but it was based on previous studies that found evidence in favor of embodiment. Despite these limitations in the selection of word pairs, the variability associated with the selected items was taken into account in the mixed effects models as random factors, showing a relevant variance for both subjects' and items' random intercepts and slopes. In this sense, future studies should try to complement the selection of stimuli with other characteristics to explain such variability in word pairs of physical, abstract, and social concepts. It is also worth mentioning that the experimental design contains some arbitrary decisions, such as the congruent and the incongruent versions of both the control and the semantic relation conditions, which were artificial. Congruent/incongruent conditions were assigned completely at random for the control and the sematic relation words (both control conditions); yet this decision was necessary in order to balance the different conditions of the experimental design.

CONCLUSIONS

This experiment was focused on the spatial iconicity effect (Zwaan & Yaxley, 2003), but it is worth noting that embodiment theories have richer and more complex empirical foundations than this effect. Taking into account the focus of this study, we found support for the weak embodiment hypothesis as a better explanation of current results, partially limiting the interaction between conceptual knowledge and the sensory-motor system. Given the present results, we can conclude that the spatial iconicity effect is supported for physical concepts, but it should be carefully generalized to abstract and social concepts.

CONFLICT OF INTEREST

The authors have no conflicts of interest to disclose.

FUNDING INFORMATION

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ETHICS APPROVAL

Approval was obtained from the ethics committee of Universidad Autónoma de Madrid. The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

CONSENT TO PARTICIPATE

Informed consent was obtained from all individual participants included in the study. All participants were treated in accordance with the APA ethical guidelines for research.

DATA AVAILABILITY STATEMENT

The data sets generated during and/or analyzed during the current study are available from the corresponding author on reasonable request.

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