Short Communication

Implicit learning of mappings between forms and metaphorical meanings

CrossMark

Fengying Li [a,b], Xiuyan Guo [c,*], Lei Zhu [d], Zhiliang Yang [a], Zoltan Dienes [e]

[a] School of Psychology and Cognitive Science, East China Normal University, Shanghai, China
[b] Department of Psychology, Zhejiang Normal University, Jinhua, China
[c] Shanghai Key Laboratory of Magnetic Resonance and School of Psychology and Cognitive Science, East China Normal University, Shanghai, China
[d] Department of Psychology, Fudan University, Shanghai, China
[e] Sackler Centre for Consciousness Science and School of Psychology, University of Sussex, Brighton, UK

ARTICLE INFO

ABSTRACT

Previous research has shown that people can implicitly acquire mappings between word forms and literal meanings (Williams, 2004, 2005). We argue, from the metaphor-representation and embodiment perspectives, that people can unconsciously establish mappings between word forms and not only literal but also metaphorical meanings. Using Williams' (2005) paradigm, we found that transfer of form-meaning connections from a concrete domain (space) to an abstract domain (power) was achieved in a metaphor-consistent way without awareness. Our results support the view that unconscious knowledge can be flexibly deployed in an abstract way not previously explored in the implicit learning literature.

© 2012 Elsevier Inc. All rights reserved.

1. Introduction

Humans are equipped with powerful learning mechanisms for acquiring knowledge of regularities in the environment without awareness (Reber, 1989). The more flexible such knowledge is in applying to new situations, the more useful it would be. Indeed, Reber (1969) argued that implicit knowledge was abstract and could apply to new domains, perceptually different from the domain trained on (see also Altmann, Dienes, & Goode, 1995; Goschke & Bolte, 2007; Scott & Dienes, 2010; Tunney & Altmann, 2001; Turk-Browne & Scholl, 2009). By contrast, others have argued that implicit knowledge is based on storing just the details of particular exemplars (e.g. Brooks & Vokey, 1991; Jamieson & Mewhort, 2011) or their parts (e.g. Dulany, Carlson, & Dewey, 1984; Perruchet & Pacteau, 1990; Servan-Schreiber & Anderson, 1990). Both sides of the debate have made compelling demonstrations; for example, the exemplar view has demonstrated just how well a system can generalize even though learning consists only of storing studied exemplars (Dienes, 1992; Jamieson & Hauri, 2012; Pothos, 2007). On the other hand, it has also been shown that people can implicitly learn abstract structures, such as melodic structure, symmetries or recursive embeddings, above and beyond the chunk structure or even repetition patterns of individual exemplars (e.g. Jiang et al., 2012; Rohrmeier, Fu, & Dienes, 2012; Rohrmeier, Rebuschat, & Cross, 2011). Here we explore implicit learning involving a different type of abstract knowledge: the metaphorical relation between something concrete and the more abstract idea it represents (Boroditsky, 2000; Boroditsky & Ramscar, 2002; Lakoff & Johnson, 1980, 1999). That is, implicit learning may be a mechanism by which embodied concrete knowledge extends into the conceptual abstract domain.

Metaphor is at least one way people understand abstract concepts (e.g., time) by using knowledge of a more concrete domain (e.g., space). Cognitive linguists (e.g., Lakoff & Johnson, 1980, 1999) have argued that most metaphors are

* Corresponding author at: School of Psychology and Cognitive Science, East China Normal University, North Zhongshan Road 3663, Shanghai 200062, China. Fax: +86 21 67644201.
E-mail addresses: xyguo@psy.ecnu.edu.cn, xyguo2006@gmail.com (X. Guo).

unconsciously and automatically learned. The major goal of the current research was to explore whether unconscious knowledge acquired through implicit learning could transfer from a concrete domain to an abstract one in a metaphor-consistent way. This issue was addressed by adopting a paradigm introduced for investigating word form-meaning connections (Williams, 2004, 2005). In Experiment 1 of Williams (2005), participants were first taught four novel words (gi, ro, ul and ne, which were introduced as determiners) and told that they encoded a certain meaning dimensions (gi and ro occurred with near objects, ul and ne with far objects). What they were not told was that the use of determiners also depended on the animacy of the nouns (gi and ul were used with animate nouns and ro and ne with inanimate nouns). The novel words were embedded in English sentences (e.g., "At the fair they threw balls at ne plates."). In training, participants had to repeat the sentences, indicate whether the novel word meant near or far, and form a mental image of the situation portrayed by the sentence. In testing, participants were exposed to novel contexts and had to choose between two possible determiners, one of which violated the animacy rule (e.g., "After my meal I went to the sink to wash ro/gi cup."). With oral report, 33 out of 41 of the participants remained unaware of the relevance of animacy to determiner usage. Nonetheless, they performed significantly above chance in selecting appropriate determiner for a noun, even though that determiner-animacy combination had never been encountered during training. This finding provided evidence of implicit leaning of form-meaning connections (see also Leung & Williams, 2011).

Word form-meaning connections are more complicated than a word form having a one-to-one correspondence with a literal meaning (VanPatten, Williams, Rott, & Overstreet, 2004). A word may have both literal and metaphorical senses. For example, "high" means "having a relatively great elevation" as in "a high tower" literally and "eminent in rank or status" as in "a high official" metaphorically. Spatial height and social power correspond to the literal and metaphorical meanings of "high" respectively. Schubert (2005) suggested that activation of meanings of height primes the meaning of power automatically. He asked participants to evaluate pairs of powerful and powerless groups (e.g., captain-sailor) presented on a computer screen. Participants reacted faster when powerful groups were presented at the top and powerless groups were shown at the bottom of the screen. This is a typical case of the "high status is up" metaphor (Lakoff & Johnson, 1980). This argument converges with theories of embodied cognition (Barsalou, 1999, 2008; for a review, see Niedenthal, Barsalou, Winkielman, Krauth-Gruber, & Ric, 2005), which posit that people use concrete physical experience in their abstract conceptual thinking. So, the current study sought to use a vertical representation of power (Giessner & Schubert, 2007; Lakoff & Johnson, 1980, 1999; Schubert, 2005) to explore whether the transfer of form-meaning connections from a concrete domain (e.g., space) to an abstract domain (e.g., power) can be achieved unconsciously, using the paradigm of Williams (2005).

A central question to implicit learning research is how we can be sure that implicit, rather than explicit, learning took place. Williams (2004, 2005) addressed the question with free report. In addition to this method, there are three subjective measures used to assess the conscious status of the knowledge. The zero-correlation criterion (Dienes & Berry, 1997) posits that knowledge is unconscious when there is a lack of correlation between confidence and accuracy. The guessing criterion (Cheesman & Merikle, 1984) states that if people perform above chance when they believe they are guessing, the knowledge is unconscious. However, Dienes and Scott (2005) argued that the zero-correlation and guessing criteria only assess the conscious status of judgment knowledge (knowledge about whether a particular test item has the same structure as the training items) rather than of structural knowledge (knowledge of the structure of the training items). Based on the distinction between judgment knowledge and structural knowledge, Dienes and Scott (2005) developed a third subjective measure – trial-by-trial structural knowledge attributions – to assess the conscious status of the knowledge of the structure of a domain. After a judgment, participants made one of four attributions about the basis of their judgment. "Guess" indicated that the judgment was based on nothing at all, it could just as well be based on a toss of a coin; "Intuition" indicated that the judgment was based on a hunch or feeling that could not be explicated further, i.e. there was confidence in the judgment but the person had no idea why the judgment was right; "Memory" indicated that the judgment was based on a recollection; "Rules" indicated that the judgment was based on a rule that could be stated if asked. Among the four attributions, 'guess' and 'intuition' are prima facie cases of unconscious structural knowledge and 'rules' and 'memory' of conscious structural knowledge. By using this measure, Chen et al. (2011) conducted a study with Chinese phrases showing the existence of unconscious knowledge of word form-literal meaning connections, confirming the findings of Williams (2005). As trial by trial subjective measures are particularly sensitive measures of the conscious status of knowledge (Norman, 2010; Ziori & Dienes, 2006), the current study sought to explore the conscious status of knowledge by using confidence ratings and the structural knowledge attributions of Dienes and Scott (2005) (see also Guo et al., 2011; Rebuschat, 2008, for additional applications of these measures to language learning).

In sum, we hypothesized people can unconsciously transfer their knowledge of form-meaning connections from a concrete domain to an abstract domain in a metaphor-consistent way.

2. Method

2.1. Participants

Sixteen volunteers (eight females) with an average age of 22.63 years (SD = 4.33) from the university community participated in this study.

2.2. Materials

2.2.1. Determiners

Four Chinese characters (亍, 夬, 疋 and毛) which are identical to those used in Chen et al. (2011), were taken as determiners in their reduplicated forms (e.g.,亍亍的) to modify nouns. They were selected from the Dictionary Editing Office of the Institute of Language in the Dictionary Editing Office of Institute of Language in Chinese Academy of Social Science (1990), with frequencies lower than 1/1,000,000 (National Language Committee, 1992). They were assigned pronunciations (chù, gè, lí, mó) in such a way as to minimize semantic association with distance, verticality and power. None of our participants knew the actual meaning of these characters.

2.2.2. Nouns standardization

Sixty nouns were selected. Among them, 40 nouns were clear cases of high or low objects, 20 nouns of each class. Half of each class was randomly assigned to training or testing phrase. The remaining 20 nouns (used only for testing) were clear cases of powerful or powerless social roles, 10 nouns of each class. To ensure it was the case, an independent sample ($N = 20$) rated nouns on 7-point bipolar scales (see Table 1). The highness ratings were significantly higher for nouns which specified high rather than low objects for training and testing phases respectively (all $ps < .001$), while familiarity, valence and size of objects specified by object nouns were controlled (all $ps > .1$). The power ratings were significantly higher for nouns specified powerful rather than powerless social roles ($p < .001$), while familiarity and valence were controlled (all $ps > .1$).

2.2.3. Materials construction

There were two critical rules guiding the determiners before nouns: the distance rule and the height rule. The distance rule specified whether the objects specified by the noun phrases were relatively near to or far from the subject. The height rule specified whether the objects denoted by the noun were high (e.g., sky) or low (e.g., ground) in space. In one version of the materials, "亍" was designed to modify high and near objects, "毛" to low and near objects, "疋" to high and far objects, and "夬" to low and far objects. For example, "亍亍的天空" means "the sky (high) is relatively near to the subject, while "疋疋的天空" means "the sky (high) is relatively far from the subject". A second version of the materials was constructed, in which assignments of the determiners were reversed with respect to height, so that "亍" and "疋" modified low objects and "毛" and "夬" modified high objects.

Ten nouns of each height category (high vs. low) assigned for training occurred with both possible determiners (e.g., "亍亍的天空" and "疋疋的天空"), resulting in 40 training items in all (Appendix A).

The materials for the test phase consisted of 40 noun phrases without determiers (e.g., _山头"_hilltop"). None of the nouns used for testing had been presented during the training phase. Twenty nouns denoting high or low objects were reffered to as literal generalization test items. Another 20 nouns denoting powerful or powerless social roles were reffered to as metaphorical generalization test items. Each noun phrase was tested in both near and far situations. Thus, there were 80 testing items in all, 40 of which were literal generalization test items and 40 metaphorical generalization test items (Appendix B).

2.3. Procedure

2.3.1. Vocabulary pretraining

Initially, participants were told that they would be learning four new Chinese characters (亍, 夬, 疋, and毛) and these characters were used as determiners in reduplicated forms to portray the relative distance of an object from them. They were also told that "亍亍的" and "毛毛的" were associated with "near", while "疋疋的" and "夬夬的" were associated with "far". Participants were presented with each character and asked to give its pronunciation and meaning (near or far) until they could go through all four characters without error.

2.3.2. Training

Each noun phrase was presented one at a time on the computer screen. Participants were instructed to (a) read the noun phrase aloud and give the meaning of the phrase, (b) form a mental image of the phrase while reading it for three times and (c) press the corresponding key(d/k) to indicate whether it means "near" or "far". For example, the participants would see "疋

Table 1
Stimulus characteristics ($M \pm SD$).

Features	Location (training)		Location (testing)		Power	
	High	Low	High	Low	Powerful	Powerless
Valence	4.55 ± 0.81	4.12 ± 0.27	4.43 ± 0.52	4.40 ± 0.70	4.13 ± 0.54	4.37 ± 0.42
Familiarity	5.14 ± 1.20	5.36 ± 0.99	5.29 ± 0.92	5.30 ± 0.92	5.40 ± 0.58	5.59 ± 0.94
Height	5.35 ± 0.87	2.25 ± 0.42	5.18 ± 0.62	1.96 ± 0.46		
Size	4.28 ± 1.15	3.33 ± 1.56	4.38 ± 0.85	4.30 ± 1.04		
Power					5.82 ± 0.63	2.42 ± 0.43

定的天空", read "疋疋的天空", say "近的天空" (the near sky), and imagine the situation that the sky is near from him/her while reading aloud the phrase three times, and press "d". Accuracy feedback was provided. The presentation order of the training set was randomized. The assignment of determiners to low/high was counterbalanced across participants.

2.3.3. Testing

Immediately after the training phase, the participants were tested on the height rule by a phrase completion task. For each test item, the computer displayed one phrase without a determiner (e.g., "_山头", 山头means hilltop) and two alternative completions (丁丁的/毛毛的) below the phrase. The two options indicate the same distance but different height (e.g., both "丁丁的" and "毛毛的" indicate "near", but "丁丁的" indicates "high" and "毛毛的" indicates "low"). For each trial, the participants were asked: (1) to choose one of the alternatives on the basis of what they had experienced during the training task; (2) to rate their confidence in their choice on a scale from 50% to 100% (where 50% = chance of being right or wrong, 100% = complete certainty) and (3) to indicate what they believed to be the basis for their decision (guess, intuition, memory or rules). These decision strategies were defined as follows: Guess – you had no idea so you literally chose either option at random, you may as well flipped a coin; Intuition – you had some confidence in your choice but no idea why it was right; Memory – your choice was based on a recollection of training material; Rules – you based your answer on one or more rules or partial rules that you obtained in the training stage and you could state if asked.

The trials of each generalization test were presented in the same order for half of the participants. The trial order was reversed for the other half. Test order (literal generalization first vs. metaphorical generalization first) was counterbalanced across participants.

3. Results

After the experiment, the participants were asked what criteria they had used to make their choices. All of them claimed to have based their choices on feelings or literally guesses, and were not able or willing to explicate further.

3.1. Proportion of correct responses

The proportion of correct response was calculated by $\frac{N_C+0.5}{N+1}$ (N_C being the number of correct responses; and N the total number of responses), the correction corresponding to a Bayesian prior of chance performance worth just one observation, useful when there is low N (a procedure used by e.g. Dienes & Scott, 2005).

The overall percentage of correct response was 59% ($SD = 0.14$), significantly above chance (50%), $t (15) = 2.45$, $p < .05$, $d = 0.61$, indicating that learning took place. For literal generalization, the percentage of correct responses was 57% ($SD = 0.12$), significantly better than chance ($t (15) = 2.36$, $p < .05$, $d = 0.59$). For metaphorical generalization, the percent correct was 60% ($SD = 0.18$), also significantly better than chance ($t (15) = 2.25$, $p < .05$, $d = 0.56$).

3.2. Judgment knowledge

According to the guessing criterion (Cheesman & Merikle, 1984), knowledge is unconscious when participants think that they are guessing but in fact performing above chance. When participants gave a confidence rating of 50%, the overall classification performance was 59% ($SD = 19\%$), significantly above 50%, $t (15) = 1.85$, $p < .05$, one-tailed, $d = 0.46$, suggesting that the guessing for unconscious judgment knowledge was satisfied. For literal generalization, participants' classification performance was 51% ($SD = 21\%$) when they gave a confidence rating of 50%, not significantly difference from chance level, $t (12) = .21$, $p > .05$, $d = 0.06$. While the result being non-significant appears not to satisfy the guessing criterion of unconscious knowledge, a non-significant result in itself cannot be used to assert the null hypothesis. Thus, we analyzed the result further with a Bayes Factor (Dienes, 2008, 2011). To interpret a null result one needs to know what size effects could be expected if they existed. Chen et al. (2011) tested literal generalization in a similar paradigm (but for learning animacy rather than height) and found accuracy for responses based on unconscious structural knowledge for generalization items was 55% (in experiment 1). Thus, we modeled an expectation for knowledge with confidence rating of 50% with a half-normal with a mode of zero and a standard deviation of 5% (following the recommendations of Dienes, 2011, Appendix). For literal generalization, the mean difference between the experimental and chance level in percentage correct for knowledge when participants gave a confidence rating of 50% was 1%, with a standard error of difference of 5%. The Bayes Factor (using the online calculator for the website for Dienes, 2008) in favor of the existence of unconscious knowledge over the null hypothesis of no unconscious knowledge was 0.80, close to 1, indicating no sensitivity in the data for picking up whether or not there was unconscious knowledge (for other applications of Bayes to implicit learning, see Dienes, Baddeley & Jansari, 2012; Jiang et al., 2012; Mealor & Dienes, 2012). For metaphorical generalization, participants' classification performance was 63% ($SD = 21\%$) when they gave a confidence rating of 50%, significantly above chance, $t (15) = 2.54$, $p < .05$, $d = 0.64$, indicating that the guessing criterion was satisfied. A paired t-test indicated no significant difference between literal and metaphorical generalization in correct percentage with confidence rating of 50% ($t (12) = 1.75$, $p > .05$, $d = 0.49$).

According to the zero-correlation criterion, knowledge is unconscious when people cannot distinguish states of guessing from states of knowing, as shown by no relation between accuracy and "guess" vs. "some confidence" responses. In terms of

Table 2
Response proportion and mean accuracy when participants were guessing (50% confidence rating) or confident (51–100% confidence rating) and the number of participants who were included in the analysis.

		Response proportion (%)	N	Response accuracy
Overall	Guess	0.33 ± 0.27	16	0.59 ± 0.19
	Confident to any degree	0.67 ± 0.27	16	0.63 ± 0.20
LG	Guess	0.33 ± 0.32	13	0.51 ± 0.21
	Confident to any degree	0.67 ± 0.32	15	0.62 ± 0.18
MG	Guess	0.34 ± 0.25	16	0.63 ± 0.21
	Confident to any degree	0.66 ± 0.25	16	0.64 ± 0.23

Note: LG = Literal Generalization; MG = Metaphorical Generalization.

showing unconscious knowledge, it is specifically the distinction between completely guessing and having any confidence that is important (Dienes, 2004), so we divided confidence between 50% (pure guessing) and any other value (51–100%). Table 2 shows the accuracy for such guess and confident responses. For literal generalization, the difference in accuracy (the accuracy-confidence "slope") was 11.4% ($SD = 27.4\%$), was not significant, $t(11) = -1.44$, $p > .05$, $d = .42$, appearing to satisfy the zero correlation criterion of unconscious knowledge. We also further analyzed the null results with a Bayes Factor. It can be shown that the maximum slope that can be obtained depends on the proportion of confident responses, pc; specifically if the overall accuracy (ignoring confidence) is $X\%$ above baseline, then the maximum slope possible is X/pc.[1] Thus, the theory that there exists some conscious knowledge can be represented as a uniform between 0 and X/pc. That is, conscious knowledge, if it exists, is assumed to be possibly any value from infinitesimally small to the maximum allowed. For the current data, $X = 7\%$, $pc = .67$, thus maximum slope = 10%. With this assumption the Bayes Factor (using the online calculator for the website for Dienes, 2008) was 1.89. That is, the data are insensitive, and nothing can be concluded about whether or not there was conscious knowledge, as measured by the zero correlation criterion. For metaphorical generalization, the difference in accuracy (the accuracy-confidence "slope") was -0.7% ($SD = 30\%$), was not significant, $t(15) = -0.09$, $p = .93$, $d = .02$, also appearing to satisfy the zero correlation criterion of unconscious knowledge. However, further analysis showed that the Bayes Factor was 0.63. Thus, the data are also insensitive, and nothing can be concluded about whether or not there was conscious judgment knowledge, as measured by the zero correlation criterion.

3.3. Structural knowledge

The response proportions of each attribution are shown in Table 3. Few attributions reflected conscious knowledge and only five participants gave explicit attributions at all. Therefore we did not include explicit attributions in the following analyses. The proportion of correct responses for guess and intuition attributions of each condition is shown in Table 4 and Fig. 1. Guess and intuition attributions were combined as indicators of unconscious structural knowledge (implicit attributions), and memory and rule attributions were combined as indicators of conscious structural knowledge (explicit attributions) (Dienes & Scott, 2005).

For both generalization tests, correct responses of implicit attributions were significantly above chance ($M = 0.57$, $SD = 0.12$, $t(15) = 2.42$, $p < .05$, $d = 0.61$ for literal generalization and $M = 0.60$, $SD = 0.17$, $t(15) = 2.28$, $p < .05$, $d = 0.57$ for metaphorical generalization respectively). The accuracy observed in the generalization tests arose predominantly, if not exclusively, from unconscious structural knowledge, as shown by the high proportion of implicit responses, suggesting individuals implicitly established mappings between forms and both literal and metaphorical meanings unconsciously.

Comparing the two generalization tests on implicit structural knowledge, a paired t-test indicated no significant difference ($t(15) = 0.91$, $p > .05$, $d = 0.17$).

4. Discussion

The present study revealed that people became sensitive to mappings between meanings of literal height and novel words without awareness, which conceptually replicates Williams (2004, 2005), Leung and Williams (2011) and Chen et al. (2011) findings that people become sensitive to form-meaning connections implicitly. Importantly, our data extended prior work by showing that people also became sensitive to form-metaphorical meaning connections. Notably, this occurred when the knowledge was unconscious, as determined by trial-by-trial subjective measures. As predicted, transfer of form-meaning connections from a concrete domain to an abstract domain was achieved in a metaphor-consistent way without awareness.

---

[1] X is a weighted average of the performance above baseline when guessing (G) and when confident (C), with the weights being the proportions of each type of response. That is, $X = (1 - pc) * G + pc * C$. By definition, our measure of confidence accuracy relation, the slope, is $C - G$. This will be maximum when all guessing responses are at baseline, i.e. when $G = 0$. In this case, slope = $C - G = C$. Also in this case, $X = pc * C$, with the G term dropping out. Rearranging, $C = X/pc$. Thus, since maximum slope = C in this case, maximum slope = X/pc.

Table 3
Response proportions of each attribution for each type of generalization tests ($M \pm SD$).

|	Implicit attributions		Explicit attributions	
	Guess	Intuition	Memory	Rule
LG	0.39 ± 0.29	0.58 ± 0.28	0.02 ± 0.05	0.00 ± 0.00
MG	0.43 ± 0.27	0.56 ± 0.26	0.01 ± 0.02	0.001 ± 0.013

Note: LG = Literal generalization; MG = metaphorical generalization.

Table 4
Mean accuracy of each condition.

Literal generalization		Metaphorical generalization	
Guess	Intuition	Guess	Intuition
0.54 (0.13) [0.46, 0.61]	0.58 (0.16) [0.49, 0.67]	0.62 (0.13) [0.55, 0.69]	0.61 (0.22) [0.49, 0.73]

Note: means with *SD*s in parentheses and 95% confidence interval in square brackets.
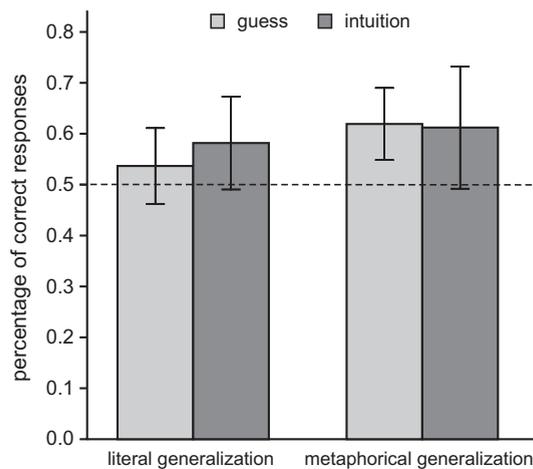
Fig. 1. Percentage of correct responses by guess and intuition attributions for each generalization test. Error bars indicate 95% confidence interval.

The unconscious nature of the knowledge was shown both by confidence ratings and structural knowledge attributions. Confidence ratings refer to confidence in the accuracy of the judgment that a form is appropriate, and hence measure the conscious status of judgment knowledge; i.e. whether one is aware of knowing that a form is appropriate in context. Structural knowledge attributions determine if the subject is aware of the basis of their judgment. The guess attribution should rationally always be given the 50% confidence attribution (just occasionally subjects give a higher confidence rating, contrast Tables 2 and 3, due to either the natural variability inherent in any measurement, or else context effects due to other points on the scale; cf Dienes & Seth, 2010a, 2010b). Thus, both guess attributions and 50% confidence ratings prima facie indicate both judgment and structural knowledge are unconscious; a good third of responses fell into this category. Intuition attributions indicate conscious judgment knowledge and unconscious structural knowledge. Virtually all the judgments were attributed to either guessing or intuition and thus, structural knowledge was largely, if not entirely, unconscious in our study. Subjects almost never said they based their judgments on rules or memories, which would have indicated some conscious structural knowledge.

Previous studies (Chen et al., 2011; Leung & Williams, 2011) have shown similar implicit learning effects for the animacy distinction. However, no learning of a distinction based on relative size occurred in either study (Chen et al., 2011; Leung & Williams, 2011). Why did people not learn a size distinction in previous studies but did learn a height distinction in this study? Leung and Williams (2011) proposed two factors that may affect learnability in the paradigm: conceptual availability and linguistic relevance. We consider each in turn. According to Caramazza and Mahon (2003), there is an evolutionary advantage in detecting animacy, making the concept chronically conceptually available. In training, the rapid automatic activation of animacy may have allowed implicitly associating form and meaning. However, relative size is not an intrinsic object property and has to be computed, introducing processes taking time and thus reducing learning of form–meaning connections (Leung & Williams, 2011). According to this account, a property is of evolutionary value can easily figure in implicit learning. In the

current case, the rule is about height, which is relevant in many situations for deciding whether to hold one's ground or retreat (Judge & Cable, 2004). The ratings of height by an independent sample (used in the nouns standardization phase) indicated that the high/low distinction of the objects is salient. Specifically, high objects were perceived as higher (M = 5.26, SD = 0.74) than low objects were (M = 2.11 SD = 0.46), t(38) = 16.27, P < .01. We also computed the absolute difference between the height rating of each word and the neutral midpoint 4. The difference were significant for each of high and low nouns (t = 7.64, P < .01 for high object nouns and t = 18.59, P < .01 for low object nouns). Therefore, an automatic distinction was plausibly automatically made by subjects between high/low objects. In contrast, the size regularities used in previous studies – the relative size of two objects (Leung & Williams, 2011) or size of an animal relative to a dog (Chen et al., 2011) – are either not intrinsic features of an object or not ones likely to be evolutionarily selected for automatic encoding. For example, a pig was large and a monkey was small in Chen et al. (2011) study. But people may not perceive a pig as large or a monkey as small automatically. Thus, the arbitrariness of the distinction based on size might reduce the likelihood of establishing a form-meaning connection.

An alternative explanation assumes the linguistic relevance may be a critical factor in implicit learning (Leung & Williams, 2011; also see in Chen et al., 2011). According to this account, people can learn form-meaning connections based on animacy because animacy is the kind of information existing in the participants' prior grammatical knowledge, while relative size is not. This account also makes sense in our case. Chinese classifiers can be sensitive to height. For example, "座" modifies high objects (e.g., 一座山 "a mountain"), while "簇" modifies "low" objects (e.g., 一簇草 "a tuft of grass"). No Chinese classifier is sensitive to relative size nor to size relative to a dog. In short, conceptual availability and linguistic relevance cannot yet be distinguished as an explanation for what is implicitly learned in the form meaning paradigm, and this would be an interesting area for future research to explore. Whether conceptual availability or linguistic relevance turns out to contribute to learning, each is an example of the relevance of prior knowledge and expectations in determining what is implicit learned (Ziori & Dienes, 2008).

The current study is important in supporting the view that unconscious knowledge can be flexibly deployed (Reber, 1989) by showing that people could unconsciously transfer knowledge from the domain of space to the superficially dissimilar and semantically different domain of power. Our data indicated that people can beyond the most concrete representation of a stimulus in forming unconscious knowledge (cf e.g., Altmann et al., 1995; Goschke & Bolte, 2007; Reber, 1969, 1989; Scott & Dienes, 2010), and use existing metaphorical connections to unconsciously generalize. However, the data not do distinguish between rule and exemplar models of learning in themselves. But if only exemplars are stored, the comparison of test items to training exemplars needs to be sensitive to both literal and metaphorical similarity, i.e. the model needs to include a type of generalization (metaphorical) a priori built into it.

Metaphorical transfer is consistent with the metaphor-representation perspective (Gibbs, 1994; Lakoff & Johnson, 1980, 1999) and the embodied cognitive theories (Barsalou, 1999, 2008; for a review, see Niedenthal et al., 2005). Human cognition is postulated to be body based by these theories, that is, off-line conceptualization is through the activation of bodily experience related to those concepts (Meier et al., 2007). For example, Williams and Bargh (2008) showed that manipulation of bodily states (e.g., physical warmth) produced the metaphor-consistent changes in the perception of psychological warmth of others. Similarly, in our study, the bodily experience of spatial height activated by the imagination task might have activated the metaphorically related concept of power. The close connection of concrete and abstract domains could be explained by assuming that mental representations of abstract concepts contain sensory-motor representations (e.g., Barsalou, 1999; Wilson, 2002). However, future research is still needed to clarify the mechanisms of embodied cognition more precisely.

Lakoff & Johnson, 1999 originally proposed that "the greater inferential complexity of the sensory and motor domains gives the metaphors an asymmetric character, with inferences flowing in one direction only" (pp. 57–58). However, some studies have provided bi-directional influences between metaphorically related domains by showing information about a leader's power subsequently influenced participants' vertical positioning of a leader in space (Giessner & Schubert, 2007). If bi-directional influence does occur, the reverse causal effect should be observed with the current paradigm. Further research might address this issue.

Our study makes use of a pre-existing metaphor and leaves open the question of how it might originally have been acquired. Children find that their taller parents have power over them (Schubert, 2005), thus from a social learning perspective superiority in stature and parental dominance might become associated (Schwartz, Tesser, & Powell, 1982). From the evolutionary perspective, as Freedman (1979) noted, "throughout nature the rule is the bigger, the more dangerous" (p. 29). Similarly, Fiske (2004) proposed that human may be evolutionarily designed to pick up associations of power and spatial positions. Given the importance of the relationship between spatial height and power, people may become especially sensitive to it. Our results provide evidence for the importance of such an association. Future studies could investigate the implicit learning of a new metaphor.

5. Conclusion

To conclude, the current study is among the first to extend the metaphor perspective to the realm of implicit learning, providing evidence that people implicitly transfer their knowledge of form-meaning connections from a concrete domain to an abstract domain in a metaphor-consistent way. These findings extend the prior work (Chen et al., 2011; Leung & Williams, 2011; Williams, 2004, 2005) by suggesting that people can automatically establish mappings between form and both literal and metaphorical meanings.

Appendix A. Noun phrases in the training phase

High		Low	
Near	Far	Near	Far
chù chù de sky	lí lí de sky	mó mó de ground	gè gè de ground
亍亍的天空	疋疋的天空	毛毛的地面	夬夬的地面
chù chù de sun	lí lí de sun	mó mó de cushion	gè gè de cushion
亍亍的太阳	疋疋的太阳	毛毛的坐垫	夬夬的坐垫
chù chù de ceiling	lí lí de ceiling	mó mó de stump	gè gè de stump
亍亍的天花板	疋疋的天花板	毛毛的树墩	夬夬的树墩
chù chù de louver	lí lí de louver	mó mó de pedal	gè gè de pedal
亍亍的天窗	疋疋的天窗	毛毛的踏板	夬夬的踏板
chù chù de top roof	lí lí de top roof	mó mó de tunnel	gè gè de tunnel
亍亍的顶棚	疋疋的顶棚	毛毛的隧道	夬夬的隧道
chù chù de skyscraper	lí lí de skyscraper	mó mó de hillfoot	gè gè de hillfoot
亍亍的摩天楼	疋疋的摩天楼	毛毛的山脚	夬夬的山脚
chù chù de beacon tower	lí lí de beacon tower	mó mó de horse	gè gè de horse
亍亍的烽火台	疋疋的烽火台	毛毛的坐骑	夬夬的坐骑
chù chù de iron tower	lí lí de iron tower	mó mó de saddle	gè gè de saddle
亍亍的铁塔	疋疋的铁塔	毛毛的马鞍	夬夬的马鞍
chù chù de ridge	lí lí de ridge	mó mó de shoes	gè gè de shoes
亍亍的屋脊	疋疋的屋脊	毛毛的鞋子	夬夬的鞋子
chù chù de lighthouse	lí lí de lighthouse	mó mó de doorsill	gè gè de doorsill
亍亍的灯塔	疋疋的灯塔	毛毛的门槛	夬夬的门槛

Appendix B. Noun phrases in the testing phase

Literal generalization		Metaphorical generalization	
High	Low	Powerful	Powerless
_云层 cloud	_地毯 carpet	_泰斗 leading figure	_孩子 kid
_山峰 mountain	_矿井 mine	_总裁 chief executive	_学生 student
_天桥 overbridge	_山谷 valley	_官员 official	_助教 assistant instructor
_屋顶 roof	_海底 seafloor	_盟主 alliance leader	_士女 palace maid
_塔楼 pagoda	_田埂路 ridge	_权威 pundit	_农夫 farm
_山头 hilltop	_车轮 wheel	_国王 king	_水手 sailor
_城楼 city tower	_草地 grassland	_船长 sea captain	_护士 nurse
_旗杆 flagpole	_山坳 col	_队长 head	_乘客 passenger
_炮台 emplacement	_河谷 river valley	_院长 dean	_队员 team member
_顶峰 summit	_地板 floor	_老板 boss	_丫头 maid

References

Altmann, G., Dienes, Z., & Goode, A. (1995). On the modality independence of implicitly learned grammatical knowledge. *Journal of Experimental Psychology: Learning, Memory, & Cognition, 21*, 899–912. http://dx.doi.org/10.1037//0278-7393.21.4.899.
Barsalou, L. W. (1999). Perceptual symbol systems. *Behavioral and Brain Sciences, 22*, 577–609. http://dx.doi.org/10.1017/S0140525X99002149.

Barsalou, L. W. (2008). Grounded cognition. *Annual Review of Psychology, 59*, 617–645. http://dx.doi.org/10.1146/annurev.psych.59.103006.093639.

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition, 75*, 1–28. http://dx.doi.org/10.1016/S0010-0277(99)00073-6.

Boroditsky, L., & Ramscar, M. (2002). The roles of body and mind in abstract thought. *Psychological Science, 13*, 185–189. http://dx.doi.org/10.1111/1467-9280.00434.

Brooks, L. R., & Vokey, J. R. (1991). Abstract analogies and abstracted grammars: Comments on Reber (1989) and Mathews et al. (1989). *Journal of Experimental Psychology: General, 120*(3), 316–323. http://dx.doi.org/10.1037//0096-3445.120.3.316.

Caramazza, A., & Mahon, B. Z. (2003). The organization of conceptual knowledge: The evidence from category-specific semantic deficits. *Trends in Cognitive Sciences, 7*, 354–361. http://dx.doi.org/10.1016/S1364-6613(03)00159-1.

Cheesman, J., & Merikle, P. M. (1984). Priming with and without awareness. *Percept Psychophys, 36*, 387–395. http://dx.doi.org/10.3758/BF03202793.

Chen, W., Guo, X., Tang, J., Zhu, L., Yang, Z., & Dienes, Z. (2011). Unconscious structural knowledge of form-meaning connections. *Consciousness and Cognition, 20*, 1751–1760. http://dx.doi.org/10.1016/j.concog.2011.03.003.

Dictionary Editing Office of Institute of Language in Chinese Academy of Social Science (1990). *A dictionary of modern Chinese*. Beijing: The Commercial Press.

Dienes, Z. (1992). Connectionist and memory array models of artificial grammar learning. *Cognitive Science, 16*, 41–79. http://dx.doi.org/10.1016/0364-0213(92)90017-O.

Dienes, Z. (2004). Assumptions of subjective measures of unconscious mental states: Higher order thoughts and bias. *Journal of Consciousness Studies, 11*, 25–45.

Dienes, Z. (2008). *Understanding psychology as a science: An introduction to scientific and statistical inference*. Palgrave Macmillan. Book's website with Bayes Factor calculator. <http://www.lifesci.sussex.ac.uk/home/Zoltan_Dienes/inference/index.htm>.

Dienes, Z. (2011). Bayesian versus orthodox statistics: Which side are you on? *Perspectives on Psychological Sciences, 6*(3), 274–290. http://dx.doi.org/10.1177/1745691611406920.

Dienes, Z., & Berry, D. (1997). Implicit learning: Below the subjective threshold. *Psychonomic Bulletin and Review, 4*, 3–23. http://dx.doi.org/10.3758/BF03210769.

Dienes, Z., & Scott, R. (2005). Measuring unconscious knowledge: Distinguishing structural knowledge and judgment knowledge. *Psychological Research, 69*, 338–351. http://dx.doi.org/10.1007/s00426-004-0208-3.

Dienes, Z., & Seth, A. (2010a). Gambling on the unconscious: A comparison of wagering and confidence ratings as measures of awareness in an artificial grammar task. *Consciousness & Cognition, 19*, 674–681. http://dx.doi.org/10.1016/j.concog.2009.09.009.

Dienes, Z., & Seth, A. (2010b). Measuring any conscious content versus measuring the relevant conscious content: Comment on Sandberg et al.. *Consciousness & Cognition, 19*, 1079–1080. http://dx.doi.org/10.1016/j.concog.2010.03.009.

Dienes, Z., Baddeley, R. J., & Jansari, A. (2012). Rapidly measuring the speed of unconscious learning: Amnesics learn quickly and happy people slowly. *PLoS ONE, 7*, e33400. http://dx.doi.org/10.1371/journal.pone.0033400.

Dulany, D. E., Carlson, R. A., & Dewey, G. I. (1984). A case of syntactical learning and judgment: How conscious and how abstract. *Journal of Experimental Psychology: General, 113*, 541–555. http://dx.doi.org/10.1037//0096-3445.113.4.541.

Fiske, A. P. (2004). Four modes of constituting relationships: Consubstantial assimilation; space, magnitude, time, and force; concrete procedures; abstract symbolism. In N. Haslam (Ed.), *Relational models theory. A contemporary overview* (pp. 61–146). Mahwah, NJ: Lawrence Erlbaum.

Freedman, D. G. (1979). *Human sociobiology*. New York: Free Press.

Gibbs, R. W. Jr., (1994). *The poetics of mind: Figurative thought, language, and understanding*. New York: Cambridge University Press.

Giessner, S. R., & Schubert, T. W. (2007). High in the hierarchy: How vertical location and judgments of leaders' power are interrelated. *Organizational Behavior and Human Decision Processes, 104*, 30–44. http://dx.doi.org/10.1016/j.obhdp. 2006.10.001.

Goschke, T., & Bolte, A. (2007). Implicit learning of semantic category sequences: Response-independent acquisition of abstract sequential regularities. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(2), 394–406. http://dx.doi.org/10.1037/0278-7393.33.2.394.

Guo, X., Zheng, L., Zhu, L., Yang, Z., Chen, C., Zhang, L., et al (2011). Acquisition of conscious and unconscious knowledge of semantic prosody. *Consciousness and Cognition, 20*, 417–425. http://dx.doi.org/10.1016/j.concog.2010.06.015.

Jamieson, R. K., & Hauri, B. (2012). An exemplar model of performance in the artificial grammar task: Holographic representation. *Canadian Journal of Experimental Psychology, 66*(2), 98–105. http://dx.doi.org/10.1037/a0027023.

Jamieson, R. K., & Mewhort, D. J. K. (2011). Grammaticality is inferred from global similarity: A reply to Kinder (2010). *Quarterly Journal of Experimental Psychology, 64*, 209–216. http://dx.doi.org/10.1080/17470218.2010.537932.

Jiang, S., Zhu, L., Guo, X., Ma, W., Yang, Z., & Dienes, Z. (2012). Unconscious structural knowledge of tonal symmetry: Tang poetry redefines limits of implicit learning. *Consciousness & Cognition, 21*, 476–486. http://dx.doi.org/10.1016/j.concog.2011.12.009.

Judge, T. A., & Cable, D. M. (2004). The effect of physical height on workplace success and income: Preliminary test of a theoretical model. *Journal of Applied Psychology, 89*, 428–441. http://dx.doi.org/10.1037/0021-9010.89.3.428.

Lakoff, G., & Johnson, M. (1980). *Metaphors we live by*. Chicago: University of Chicago Press.

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh: The embodied mind and its challenge to Western thought*. New York: Basic Books.

Leung, J., & Williams, J. N. (2011). Constraints on implicit learning of grammatical form-meaning connections. *Language Learning, 62*, 634–662. http://dx.doi.org/10.1111/j.1467-9922.2011.00637.x.

Mealor, A. D., & Dienes, Z. (2012). Conscious and unconscious thought in artificial grammar learning. *Consciousness & Cognition, 21*, 865–874. http://dx.doi.org/10.1016/j.concog.2012.03.001.

Meier, B. P., Hauser, D. J., Robinson, M. D., Friesen, C. K., & Schjeldahl, K. (2007). What's "up" with God? vertical space as a representation of the divine. *Journal of Personality and Social Psychology, 93*, 699–710. http://dx.doi.org/10.1037/0022-3514.93.5.699.

National Language Committee (1992). *Statistics of word frequencies in modern Chinese language*. Beijing: Language and Literature Press.

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and Social Psychology Review, 9*, 184–211. http://dx.doi.org/10.1207/s15327957pspr0903_1.

Norman, E. (2010). "The unconscious" in current psychology. *European Psychologist, 15*(3), 193–201. http://dx.doi.org/10.1027/1016-9040/a000017.

Perruchet, P., & Pacteau, C. (1990). Synthetic grammar learning: Implicit rule abstraction or explicit fragmentary knowledge? *Journal of Experimental Psychology: General, 119*, 264–275. http://dx.doi.org/10.1037//0096-3445.119.3.264.

Pothos, E. M. (2007). Theories of artificial grammar learning. *Psychological Bulletin, 133*(2), 227–244. http://dx.doi.org/10.1037/0033-2909.133.2.227.

Reber, A. S. (1969). Transfer of syntactic structures in synthetic languages. *Journal of Experimental Psychoogy, 81*, 115–119. http://dx.doi.org/10.1037/h0027454.

Reber, A. S. (1989). Implicit learning and tacit knowledge. *Journal of Experimental Psychology: General, 118*, 219–235. http://dx.doi.org/10.1037//0096-3445.118.3.219.

Rebuschat, P. (2008). *Implicit learning of natural language syntax. Unpublished dissertation*. University of Cambridge.

Rohrmeier, M., Fu, Q., & Dienes, Z. (2012). Implicit Learning of recursive context-free grammars. *PLoS ONE, 7*, e45885. http://dx.doi.org/10.1371/journal.pone.0045885.

Rohrmeier, M., Rebuschat, P., & Cross, I. (2011). Incidental and online learning of melodic structure. *Consciousness & Cognition, 20*, 214–222. http://dx.doi.org/10.1016/j.concog.2010.07.004.

Schubert, T. W. (2005). Your highness: Vertical positions as perceptual symbols of power. *Journal of Personality and Social Psychology, 89*, 1–21. http://dx.doi.org/10.1037/0022-3514.89.1.1.

Schwartz, B., Tesser, A., & Powell, E. (1982). Dominance cues in nonverbal behavior. *Social Psychology Quarterly, 45*, 114–120. http://dx.doi.org/10.2307/3033934.

Scott, R. B., & Dienes, Z. (2010). Knowledge applied to new domains: The unconscious succeeds where the conscious fails. *Consciousness & Cognition, 19*, 391–398. http://dx.doi.org/10.1016/j.concog.2009.11.009.

Servan-Schreiber, E., & Anderson, J. R. (1990). Learning artificial grammars with competitive chunking. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 592–608.

Tunney, R., & Altmann, G. T. (2001). Two modes of transfer in artificial grammar learning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 27*, 614–639. http://dx.doi.org/10.1037//0278-7393.27.3.614.

Turk-Browne, N. B., & Scholl, B. J. (2009). Flexible visual statistical learning: Transfer across space and time. *Journal of Experimental Psychology: Human Perception and Performance, 35*, 195–202. http://dx.doi.org/10.1037/0096-1523.35.1.195.

VanPatten, B., Williams, J., Rott, S., & Overstreet, M. (2004). *Form-meaning connections in second language acquisition*. Hillsdale, NJ: Lawrence Erlbaum.

Williams, J. N. (2005). Learning without awareness. *Studies in Second Language Acquisition, 27*, 269–304. http://dx.doi.org/10.1017/S0272263105050138.

Williams, L. E., & Bargh, J. A. (2008). Experiencing physical warmth promotes interpersonal warmth. *Science, 322*, 606–607. http://dx.doi.org/10.1126/science.1162548.

Williams, J. N. (2004). Implicit learning of form-meaning connections. In J. Williams, B. VanPatten, S. Rott, & M. Overstreet (Eds.), *Form meaning connections in second language acquisition* (pp. 203–218). Mahwah, NJ: Lawrence Erlbaum Associates.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin and Review, 9*, 625–636. http://dx.doi.org/10.3758/BF03196322.

Ziori, E., & Dienes, Z. (2006). Subjective measures of unconscious knowledge of concepts. *Mind & Society, 5*, 105–122.

Ziori, E., & Dienes, Z. (2008). How does prior knowledge affect implicit and explicit concept learning? *Quarterly Journal of Experimental Psychology, 61*, 601–624.