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### ► To cite this version:

Luc Drouillet, Nicolas Stefaniak, Christelle Declercq, Alexandre Obert. Role of implicit learning abilities in metaphor understanding. *Consciousness and Cognition*, 2018, 61, pp.13 - 23. 10.1016/j.concog.2018.03.015 . hal-01916569

**HAL Id: hal-01916569**

**<https://hal.science/hal-01916569>**

Submitted on 27 Jun 2019

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1 **TITLE:** Role of implicit learning abilities in metaphor understanding

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- 5 **Conflict of interest:** none.
- 6

1 **Abstract**

2           Although the use of metaphors is a central component of language, the processes that  
3 sustain their comprehension have yet to be specified. Work in the fields of both metaphors and  
4 implicit learning suggests that implicit learning abilities facilitate the comprehension of  
5 metaphors. However, to date, no study has directly explored the relationships between the  
6 understanding of metaphors and so-called implicit learning tasks. We used a meaning decision  
7 task comparing literal, metaphorical and meaningless expressions to assess metaphor  
8 understanding and a probabilistic serial reaction time task for assessing implicit learning. Our  
9 results show that implicit learning positively predicts the time gap between responses to literal  
10 and metaphorical expressions and negatively predicts the difference between metaphorical and  
11 meaningless expressions. Thus, when confronted with novel metaphors, participants with higher  
12 implicit learning abilities are better able to identify that the expressions have some meaning.  
13 These results are interpreted in the context of metaphor understanding and psycholinguistic  
14 theories.

15 **Highlights**

- 16       • The role of implicit learning in the comprehension of metaphors is examined.
- 17       • Implicit learning facilitates the understanding of literal expressions.
- 18       • Rejection of meaningless expressions is enhanced by implicit learning abilities.
- 19       • The impact of implicit learning on metaphor understanding is indirect.
- 20       • Implicit learning helps to disentangle meaningful from meaningless items.

21

22 **Keywords:** implicit learning, metaphors, figurative language, language processing, statistical  
23 learning

# 1 **1. Introduction**

## 2 *1.1. Metaphors*

3 Non-literal language is a kind of language from which, beyond the literal meaning,  
4 different interpretations can be extracted (Colston & Gibbs, 2002). In addition to irony and  
5 proverbs, metaphors constitute a huge proportion of non-literal language in our daily  
6 conversations (Lakoff & Johnson, 1980). Despite their importance, the processes that are  
7 involved in the understanding of metaphors are by no means understood.

8 Metaphors are expressions in which a semantic mapping between two conceptual  
9 domains is created. For instance, the sentence “Time is a thief” does not mean that time steals  
10 things (the literal meaning) but that time passes quickly and we risk missing opportunities (the  
11 figurative meaning). The use of metaphors is so widespread in human language that it is  
12 considered to be a fundamental conceptualization strategy (Lai, 2008). Indeed, according to Lai,  
13 the act of exploring the set of correspondences from a source to a target domain allows one to  
14 better understand the target thanks to the source’s conceptual structure.

15 Different types of metaphors are described in the literature. These types can be classified  
16 according to either their frequency (i.e., conventional vs. novel metaphors) or their structure  
17 (e.g., nominal vs. verbal metaphors). Concerning frequency, conventional metaphors (e.g., “Life  
18 is a journey”) are used daily, familiar and easy to understand (Giora, 1997; Lakoff & Johnson,  
19 1980). Their meaning is nearly lexicalized and, most often, speakers do not even notice that they  
20 are using figurative language (Zufferey & Moeschler, 2015). Unlike conventional metaphors,  
21 novel metaphors are unusual in language production and their understanding depends on  
22 different cognitive processes than those involved in conventional metaphor processing (Ahrens et  
23 al., 2007). Whereas conventional metaphors are nearly lexicalized, the meaning of novel

1 metaphors requires a listener to establish links between two concepts, namely the topic and the  
2 vehicle (Zufferey & Moeschler, 2015). An example of a novel metaphor appears in the sentence  
3 “His legs are rubber,” in which “rubber” is the vehicle and “legs” the topic.

4         Regarding structure, metaphors are frequently studied in their nominal forms (“X is a Y”;  
5 e.g., “Life is a journey”) in which both X and Y belong to the grammatical category of nouns. In  
6 this kind of metaphor, the two concepts are linked by applying the terminology of the vehicle to  
7 the terminology of the topic (Kiddon & Brun, 2011). For instance, in the sentence “Experience is  
8 a candle [...],” a partial similarity of the vehicle “candle” is ascribed to the topic “experience”  
9 (Tourangeau & Sternberg, 1982). Hence, in this kind of metaphor, although the two concepts are  
10 not semantically close, a similarity is sought between them. In verbal metaphors, the focus is on  
11 the link between the verb and the vehicle (e.g., “the storm rumbles”), the topic (e.g., “the peasant  
12 tames the land”), or both (e.g., “clouds are courting the stars”) (Le Ny & Franquart-Declercq,  
13 2002; Obert et al., 2014). In other words, metaphors represent a deviation in the meaning of the  
14 words composing them (Le Ny & Franquart-Declercq, 2002).

15         Nevertheless, few studies have explored the mechanisms involved in the production and  
16 comprehension of metaphors, although several suggestions have been made. For instance, on the  
17 topic of metaphor creation, Beaty and Silvia (2012) highlighted the role of executive functions.  
18 As for their understanding, an analogical mapping of different similarity levels, such as the  
19 attributes of the concept (in nominal metaphors) or their relations (in verbal metaphors), is  
20 required (Glucksberg, McGlone, & Manfredi, 1997; Holyoak & Koh, 1987; Le Ny & Franquart-  
21 Declercq, 2002). Thus, the understanding of nominal metaphors requires that the vehicle and the  
22 topic share identifiable common properties (Glucksberg et al., 1997). For instance, in the  
23 metaphor “this lawyer is a shark,” one should attribute appropriate features from the vehicle

1 “shark” to the topic “lawyer” (e.g., is dangerous) and suppress inappropriate ones (e.g., has 300  
2 teeth, is a marine animal) (Fernández, 2007). According to some authors, verbal metaphors are  
3 processed in the same way as nominal ones (Glucksberg, 2003), whereas others consider that  
4 they have special status (Le Ny & Franquart-Declercq, 2002; Utsumi & Sakamoto, 2011). For  
5 example, Le Ny and Franquart-Declercq (2002) suggest that understanding verbal metaphors  
6 depends on the central meaning of the verb, as well as all the topics and vehicles that it is  
7 possible to associate with this verb. Although there seems to be no consensus on how metaphors  
8 are understood, it nevertheless appears that their understanding may depend on implicit  
9 mechanisms.

## 10 *1.2. Implicit learning*

### 11 *1.2.1. Implicit learning and language*

12 Reber (1967) was the first to suggest that language could be acquired by implicit learning  
13 mechanisms. More recently, Saffran, Aslin, and Newport (1996), who first used the term  
14 “statistical learning” (also called implicit learning; Perruchet & Pacton, 2006), showed that 8-  
15 month infants were able to segment words based only on the statistical properties of language.  
16 Since these initial publications, many studies have explored the role of implicit learning in  
17 several aspects of language. Implicit learning appears to contribute both to low-level processes  
18 and to higher-level ones (Romberg & Saffran, 2010). At a lower level, human beings can apply  
19 transitional probabilities when learning speech sounds (e.g., Frost & Monaghan, 2016). At a  
20 higher level, they can learn the syntactic structure of a language (Thompson & Newport, 2007)  
21 and use verb-related distributional information to construct and understand meaningful sentences  
22 (Thothathiri & Rattinger, 2016).

1 Yu and Smith (2007) showed that the mapping between a word and its referent was  
2 remarkably efficient in various learning conditions. Indeed, it appears that adults are highly  
3 sensitive to probabilistic relationships between a word and its meaning (Vouloumanos, 2008).  
4 Implicit learning mechanisms are also involved in second language acquisition (Pajak, Fine,  
5 Kleinschmidt, & Jaeger, 2016). Moreover, the role of implicit learning in language has been  
6 explored at the individual level: long-term storage of syntactic structures during childhood  
7 (Kidd, 2012) and language comprehension in adults are enhanced in individuals with greater  
8 implicit learning abilities (Misyak & Christiansen, 2012).

9 According to Frost and Monaghan (2016), the same class of mechanisms (i.e., statistical  
10 learning) can account for word learning and structural generalization. We suggest that these  
11 mechanisms could extend the understanding of figurative language, and specifically metaphors,  
12 more broadly. Indeed, Lidz and Gagliardi (2015) argue that the capacity to produce and  
13 understand language intrinsically depends on implicit learning mechanisms that sustain the  
14 acquisition of relevant information to make inferences about the features of the grammar (i.e., a  
15 given class of words must be followed by another specific class of words – e.g., determiners  
16 precede nouns in English). This explanation provides a framework that accounts for the capacity  
17 to produce and understand novel sentences (i.e., situations that fall outside of a person's  
18 experience). It also explains how one can distinguish possible from impossible sentences of a  
19 language.

20 This view seems coherent with the dual-path model, a connectionist model that represents how  
21 humans acquire and process language (Chang, Dell, & Bock, 2006). The architecture of this  
22 model has two pathways: a meaning system and a sequencing system. The model is rather  
23 similar to Ullman's (2001) Declarative/Procedural model since the meaning system can be

1 compared with declarative memory and the sequencing system with procedural memory. In the  
2 dual-path model, the sequencing system implicitly learns the syntactic structure of language.  
3 Interestingly, when the model learns syntactic structure, it also acquires semantic information.  
4 For instance, the model learns what kinds of things can be drunk or eaten. Thanks to the way that  
5 the sequencing system acquires semantic information about a word in position  $N$ , the model can  
6 predict what words are allowed in position  $N+1$ . For instance, the sequencing system might learn  
7 that some kinds of verbs (e.g., *kill*, *hurt*, *assassinate*) are most often followed by animate beings  
8 (e.g., humans or animals), are less often followed by abstract concepts (e.g., *hope*, *friendship*),  
9 and are never followed by inanimate objects (e.g., *rock*, *sheet*). This mechanism could explain  
10 how metaphors are understood thanks to implicit learning mechanisms.

### 11 *1.2.2. Implicit learning and metaphors*

12 An initial piece of evidence was provided by Glucksberg, Gildea, and Bookin (1982),  
13 who suggested that the understanding of metaphors is so automatic that it cannot be inhibited.  
14 This view is shared by Le Ny and Franquart-Declercq (2002), who claimed that verbal metaphor  
15 understanding relies on a form of implicit knowledge of possible verb-noun combinations. In  
16 their view, during verb processing, a verb activates various traits of its central meaning. If traits  
17 of a patient of the action are semantically congruent with the verb's traits, it will facilitate its  
18 acceptance. This could occur via the preactivation of some specific traits of the patient. A  
19 metaphor can be understood if the patient used in the metaphor belongs – even if it is unusual –  
20 to the set of possible patients of the verb. Interestingly, the set of possible patients that each  
21 individual possesses for any specific verb is hypothesized to be organized according to an  
22 implicit gradient. Similarly, Utsumi (2007) emphasized that the comprehension of metaphors can  
23 be explained by semantic richness. Given that Rabovsky, Sommer, and Rahman's (2012) study

1 showed that semantic richness depends on implicit learning, there appears to be a link between  
2 implicit learning and the comprehension of metaphors.

3           Several studies in the field of implicit learning also support this possibility. First,  
4 Kaufman et al. (2010) showed that individual differences in implicit learning, defined as the  
5 automatic and unconscious learning of complex regularities from our environment, could explain  
6 individual differences in analogical verbal reasoning. In the classical form of an analogical  
7 verbal reasoning task, one has to find the link between two *a priori* unrelated concepts. Usually,  
8 the task takes the following form: “A is to B what C is to D.” For instance,  
9 “Paris:France::Brussels:Belgium” illustrates this kind of structure. In the sentence “Paris is to  
10 France what Brussels is to ...,” one has to first spot the link between “Paris” and “France” (“is  
11 the capital of”), then apply it to “Brussels” and deduce the answer “Belgium.” In this kind of  
12 task, one has to establish links between disconnected (or unrelated) information, look at familiar  
13 things from a different angle and interpret unfamiliar things to the light of similar things (Zhao et  
14 al., 2011). Interestingly, the description of the analogical verbal reasoning task highlights the fact  
15 that it requires similar processes to those involved in understanding new metaphors (i.e., those  
16 that are not lexicalized but require the identification of shared properties to understand them).  
17 Moreover, according to Zhao et al. (2011), metaphors can be seen as part of analogical verbal  
18 reasoning because their understanding is sustained by similar reasoning. Indeed, in the nominal  
19 metaphor “this lawyer is a shark,” one has to extract the appropriate features of the topic “shark”  
20 and apply them to the agent “lawyer” in order to understand the figurative meaning of the  
21 sentence. Thus, given that implicit learning abilities are involved in analogical verbal reasoning  
22 and that understanding metaphors can be seen as a kind of analogical verbal reasoning, it seems  
23 likely that implicit learning abilities are involved in the understanding of metaphors.

1           This hypothesis was tested by Li, Guo, Zhu, Yang, and Dienes (2013). In their study,  
2 participants had to perform a task with two phases: a training phase and a testing phase. During  
3 the training phase, they were taught to use four symbols that they did not know in sentences. Two  
4 of these symbols were associated with a near distance and the other two were associated with a  
5 far distance. Participants were not told that each pair of symbols was also associated with a  
6 height-related meaning (i.e., high and low). During the training phase, each symbol was used  
7 only in descriptions of spatial height (e.g., the sky should be associated with the symbol that  
8 represents “high” and the ground with “low”). After the training phase, participants were asked  
9 to complete sentences with the symbols used in that phase. Among the target items, there were  
10 items that represented social power (e.g., “captain” – “sailor”) instead of spatial height. The  
11 authors showed that participants were able to generalize the use of the symbols to the  
12 metaphorical sense of height. According to these authors, the mapping between the literal and  
13 metaphorical meanings of the symbol was sustained by implicit learning mechanisms.

14           Although Li et al.’s (2013) study was the first to explore the role of implicit learning in  
15 metaphors, it was not able to determine whether implicit learning processes are involved in the  
16 creation or comprehension of metaphors since participants had to choose the correct symbol  
17 (which can be seen as creation) in a stipulated context (which can be seen as comprehension).  
18 According to our review, it seems more likely that implicit learning processes sustain the  
19 comprehension rather than creation of metaphors (although we cannot exclude the latter  
20 possibility). This issue can be addressed by adapting the judgment task used by Lai, Curran, and  
21 Menn (2009). In their study, participants had to indicate on a Likert scale whether an expression  
22 did or did not make some sense (i.e., perfect sense, some sense, little sense, no sense). By using  
23 this task with a binary approach (does the sentence make sense? yes/no), reaction times should

1 be less influenced by hesitation in choosing between the possible choices (e.g., for me, does the  
2 sentence make sense at level 2 or level 3?). Moreover, the use of a binary approach allows one to  
3 avoid the possibility that participants understood the different levels of the Likert scale  
4 differently (i.e., a sentence could make some sense for one individual but little sense for another,  
5 although both understood the sentence similarly).

### 6 *1.2.3. The measurement of consciousness*

7 Another limitation of Li et al.'s (2013) study is the measures used to ensure the implicit  
8 nature of the learning. They used three measures: the "zero correlation criterion," the "guessing  
9 criterion" and "trial-by-trial structural knowledge attributions." The zero correlation criterion  
10 states that knowledge is unconscious if there is no correlation between the subject's confidence  
11 in his/her answer and the answer's precision (Dienes & Berry, 1997). According to the guessing  
12 criterion, knowledge is unconscious if an individual succeeds at a task above the chance level  
13 despite thinking that he/she was guessing at the answers (Cheesman & Merikle, 1984). Finally,  
14 trial-by-trial structural knowledge attributions allow participants to assess their own structural  
15 knowledge when they are asked to judge the answers provided (Dienes & Scott, 2005). All these  
16 measures are considered to be subjective measures and have been criticized by Shanks,  
17 Lamberts, and Goldstone (2005), among others. Subjective measures are not deemed to be  
18 reliable given that they do not meet the criterion of exhaustivity (i.e., the test must be sensitive to  
19 all of conscious knowledge). These criticisms are reinforced by the fact that, for all these  
20 measures, some participants in Li et al.'s study developed some explicit awareness during the  
21 task. Moreover, Li et al. (2013) used the Bayes factor in order to determine whether explicit  
22 processes were involved in the task. Bayes factors are alternatives to null hypothesis tests. In the  
23 more simplistic situation, they are obtained by the ratio of two likelihoods (i.e., the logarithm of

1 a probability). The first likelihood is the probability that the dataset brings evidence for a given  $a$   
2 *priori* chosen difference (i.e. the presence of explicit knowledge) and the second probability is  
3 the probability that the dataset is coherent with the absence of difference (i.e., absence of explicit  
4 knowledge). If the ratio is superior to 3, it can be interpreted as supporting the presence of a  
5 difference; if it is inferior to 0.33, it can be interpreted as supporting the absence of the  
6 difference; if it is between 0.33 and 3, it is uninformative. In Li et al.'s (2013) study, the Bayes  
7 factor was uninformative on the possible involvement of explicit processes. Thus, a cautious  
8 position would not rule out the possibility that the results can, at least partly, be attributed to the  
9 intervention of explicit mechanisms. In addressing this issue, we can rely on Jiménez (2003),  
10 who has suggested that implicit learning mechanisms can be reliably assessed by a probabilistic  
11 serial reaction time task (SRT task) (see also Kaufman et al., 2010).

12         Indeed, the SRT task, developed by Nissen and Bullemer (1987), is one of the most  
13 widely used tasks for exploring implicit learning. In this task, participants are asked to respond  
14 as accurately and as quickly as possible to stimuli that appear on a screen by pressing the key  
15 that corresponds to their location on the screen. Unbeknownst to the participants, stimuli do not  
16 appear randomly but follow a sequence. Usually, there are four locations and learning is  
17 evidenced after several training blocks by shorter reaction times for the learning sequence in  
18 comparison to the reaction times for another sequence (the transfer block). In the probabilistic  
19 version of the SRT task (Schvaneveldt & Gomez, 1998), irregularities are introduced in the  
20 sequence according to a probabilistic mechanism (see section 2.2.1 for details). In such a task,  
21 implicit learning is attested to by faster responses for probable than for improbable items. This  
22 task is claimed to be less sensitive to explicit influences than the deterministic version of the task  
23 (e.g., Stefaniak, Willems, Adam, & Meulemans, 2008). In fact, the irregularities introduced in the

1 task make it almost impossible for participants to detect the sequence pattern. This is true even  
2 when participants are explicitly told about the structure of the task (Stefaniak et al., 2008). Thus,  
3 given that the probabilistic SRT task is less controversial, it can be used to reduce the issues  
4 raised by Li et al.'s (2013) study.

## 5 *2. Aims and hypotheses*

6         Although Li et al.'s (2013) study provided some initial evidence concerning the  
7 relationships between implicit learning mechanisms and metaphors, two issues remain to be  
8 addressed. The aim of our study is to address these issues by investigating the impact of implicit  
9 learning abilities on the understanding of metaphors. If implicit learning abilities are involved in  
10 analogical verbal reasoning (Kaufman et al., 2010), and if understanding metaphors is sustained  
11 by analogical verbal reasoning (Zhao et al., 2011), then we can predict that participants with  
12 better implicit learning abilities should be better able to understand metaphors.

13         More specifically, we used a meaning decision task in which participants had to decide  
14 whether they were able to make sense to verb + patient expressions. There were three categories  
15 of expressions: literal (“catapulter des pierres” [“catapult rocks”]), novel metaphorical  
16 (“catapulter des paroles” [“catapult speech”]) and meaningless (i.e., sentences for which it would  
17 be very hard to find a meaning, such as “adopter un nuage” [“adopt a cloud”]). If there is a  
18 spreading activation gradient based on the congruence between the verb and the patient (Benau,  
19 Morris, & Couperus, 2011), and if richer concepts are activated faster (Kounios et al., 2009),  
20 individuals who have larger semantic networks should be quicker at finding a meaning for literal  
21 expressions since they should have more features associated with each concept (i.e., greater  
22 semantic richness) and more patients considered as congruent with each verb (which increases

1 the probability that the patient of the expression will belong to the set of patients preactivated by  
2 the automatic spreading activation).

3         Concerning the processing of metaphors, given that we used novel metaphors, the  
4 metaphorical expressions could not benefit from automatic spreading activation. Consequently,  
5 because participants with richer semantic networks would likely explore more indirect  
6 connections, the temporal interval between literal and metaphorical expressions should be longer  
7 for those individuals. Since Rabovsky et al. (2012) showed that semantic richness depends on  
8 implicit learning, participants with larger semantic networks should have greater implicit  
9 learning abilities. Thus, the interval between the literal and the metaphorical expressions should  
10 be longer for those participants. Once spreading activation processes fail to find a preexisting  
11 meaning in the semantic networks, participants have to find possible links between the verb and  
12 the patient in order to create a meaning for a metaphorical expression. In this case, individuals  
13 must identify appropriate features of both the verb and the patient that can be used to make sense  
14 of the expression. Because the identification of similarity in a verbal reasoning task depends on  
15 implicit learning abilities, we hypothesized that participants with better implicit learning abilities  
16 would be better in identifying metaphorical meaning than participants with lower implicit  
17 learning abilities, and should be faster at finding meanings for metaphorical expressions. Finally,  
18 when an individual fails to find any meaning because the patient is impossible (i.e., meaningless  
19 expressions), the participant should decide that it is not possible to make sense of the expression.  
20 Thus, as participants with better implicit learning abilities should find meanings for metaphorical  
21 expressions quite easily but should not be able to find any meanings for meaningless  
22 expressions, the interval between metaphorical expressions and meaningless expressions should

1 be longer for participants with better implicit learning abilities than for those with lower implicit  
2 learning abilities.

## 3 **2. Method**

### 4 *2.1. Participants*

5 Eighty-six participants took part in this study (47 women; mean age: 23 years old;  
6 minimum age: 18; maximum age: 35). Exclusion criteria were the presence of learning  
7 disabilities, any history of psychiatric or speech problems, and consumption of alcohol or  
8 cannabis (or other drugs) in the last 48 hours. Inclusion criteria were to be French native  
9 speakers, aged between 18 and 35 years old. All participants signed an informed consent form.  
10 The study was carried out in accordance with the guidelines of the Helsinki Declaration.

### 11 *2.2. Materials and procedure*

12 All the participants had to perform the SRT task, a meaning judgment task and the Mill  
13 Hill vocabulary test (Deltour, 1993), in this order.

#### 14 *2.2.1. Serial reaction time task*

15 The SRT task used in the current study was constructed similarly to Kaufman et al.'s  
16 (2010) task. Participants sat in front of a computer screen on which four white arrows were  
17 presented on one horizontal line against a black background. Each location was associated with a  
18 key on the keyboard (i.e., from left to right, the “c,” “v,” “b” and “n” keys on an AZERTY  
19 keyboard). The stimuli were white dots which could appear below any of the four locations.  
20 Participants were asked to press the key corresponding to the location of each stimulus as  
21 quickly and as accurately as possible. The participants did not know that the stimuli were not  
22 randomly generated but followed a probabilistic sequence, which was produced with 85%  
23 regular and 15% irregular items. The learning sequence was a second-order conditional (SOC)

1 sequence. For half of the participants, the learning sequence was “1-2-1-4-3-2-4-1-3-4-2-3” and  
2 the irregularities were generated from a second SOC sequence, “3-1-4-2-1-3-2-3-4-1-2-4.” For  
3 instance, if a break was generated for the fourth location of the learning sequence (i.e., “4”), the  
4 irregularity was produced as follows: given that the “4” appearing in the fourth position of the  
5 learning sequence is preceded by the “2-1” association, the location of the irregularity is “3”  
6 since the “2-1” association is followed by “3” in the other sequence (for a more detailed  
7 description, see Kaufman et al., 2010). The sequences were counterbalanced for the other half of  
8 the participants. The stimulus onset asynchrony was 250 ms. The task was composed of 8 blocks  
9 of 120 items for a total of 960 stimuli. Each block was separated from the next one by a pause.

#### 10 2.2.2. *Meaning decision task*

11 Forty-seven literal (e.g., “catapult rocks”) and 47 meaningless (e.g., “adopt a cloud”) verb  
12 + patient expressions were constructed. To match the 47 literal expressions, we tried to create  
13 metaphorical expressions (e.g., “catapult speech”) with the same verb, but we succeeded for just  
14 41 of them, resulting in a total of 135 expressions (47 literal + 47 meaningless + 41  
15 metaphorical). The patients in the literal and metaphorical expressions were paired according to  
16 their frequency and length. Meaningless expressions were built from different verbs associated  
17 with different patients than in the literal and metaphorical expressions. Several of these 135  
18 expressions appeared to be equivocal (e.g., meaningless expressions for which a meaning could  
19 be found or metaphorical expressions that were not novel) and were removed from the material.  
20 After this first screening, 38 literal, 38 metaphorical (paired with the literal), and 19 meaningless  
21 expressions remained. Among these items, the literal expressions can be considered as easy,  
22 familiar and having a high imagery level; the meaningless expressions can be considered as  
23 being difficult, unfamiliar and having a having low imagery level; and the metaphorical

1 expressions fell between the literal and meaningless expressions on these three measures. We  
2 ensured that these criteria were met by asking 180 participants to judge the difficulty (on a 7-  
3 point Likert scale in which 1 = “very difficult to find a meaning” and 7 = “very easy to find a  
4 meaning”), familiarity (on a 7-point Likert scale in which 1 = “not familiar at all” and 7 = “very  
5 familiar”), and imagery scales (on a 7-point Likert scale in which 1 = “very difficult to  
6 represent” and 7 = “very easy to represent”). Each participant made only one judgment (i.e.,  
7 familiarity or difficulty or imagery) and only for (1) literal and meaningless expressions or (2)  
8 metaphorical expressions, but not both, given that the verbs were the same in the literal and  
9 metaphorical expressions. The normative data for these three measures are presented in Table 1.

10 -----  
11 INSERT TABLE 1 ABOUT HERE  
12 -----

13  
14 Participants saw a black fixation cross on a white background for 250 ms. After the  
15 fixation cross, a verb + patient expression appeared in lowercase on the screen in black  
16 characters on a white background. The expression remained on the screen until the participant  
17 responded. Participants were asked to determine whether they could find some spontaneous  
18 meaning for the expression that appeared on the screen.

19 *2.2.3. Mill Hill vocabulary test (Deltour, 1993)*

20 In this test, participants had to decide which of possibilities is the synonym of a given  
21 word. The test is composed of 34 items organized according to an increasing difficulty. One  
22 point is attributed for each correct response. This test allows researchers to determine  
23 participants’ vocabulary level in order to control for individual differences in the analyses.

### 1 3. Results

2 Statistical analyses were performed using R software (R core team, 2017), as well as the  
3 “nlme” (Pinheiro, Bates, DebRoy, Sarkar, & R core team, 2017), “psych” (Revelle, 2017), and  
4 “WRS2” (Mair, Schoenbrodt, & Wilcox, 2017) packages.

5 Data were aggregated by using the median correct responses for each participant  
6 computed separately for blocks and item and expression types in the SRT task and meaning  
7 decision task, respectively. In the meaning decision task, the response “has some meaning” was  
8 considered as correct for the literal and metaphorical expressions, while the response “has no  
9 meaning” was considered as correct for the meaningless expressions. Globally, the task was  
10 understood and performed seriously given that the mean errors were 1.76 for the literal  
11 condition, 3.49 for the metaphorical condition and 3.68 for the meaningless condition. One  
12 participant was removed from the analysis because the visual inspection of leverage measures  
13 (Cook’s Distance and hat matrix) indicated that it affected both the main analyses.

#### 14 3.1. *Implicit learning effect*

15 To determine whether learning occurred during the SRT task, we used a linear mixed  
16 model on reaction times (RTs) with Block (8 levels) and Type of item (2 levels: probable vs.  
17 improbable) as within-participant variables (i.e., crossed variables). This analysis revealed a  
18 significant effect of Block,  $F(7,588) = 8.67, p < .001$ , and a significant effect of Type of item,  
19  $F(1,672) = 130.83, p < .001$ , showing that probable items were processed faster than improbable  
20 ones. Finally, the interaction was also significant,  $F(7,672) = 6.43, p < .001$ .

21 The polynomial contrast indicated that the decrease in RTs followed a linear relationship,  
22  $t(588) = -6.42, p < .001, r^2 = 0.07$ , and that the gap between probable and improbable items also  
23 tended to increase linearly,  $t(672) = -4.21, p < .001, r^2 = 0.03$  (Figure 1).

1 -----

2 INSERT FIGURE 1 ABOUT HERE

3 -----

4 The fact that probable items were processed faster than improbable ones suggests that  
5 implicit learning occurred. Thus, it was relevant to compute a learning index for each participant.  
6 Kaufman et al. (2010) highlighted the importance of using a reliable measure of implicit learning  
7 (for a more general view, see also Siegelman & Frost, 2015). Following their recommendation,  
8 the learning index was obtained by counting the number of probable items that were processed  
9 significantly faster than the improbable items. The significance level was determined by the fifth  
10 percentile of improbable items.

11 To ensure that our measure was reliable, split-half reliability on Blocks 3 to 8, as in  
12 Kaufman et al.'s (2010) study, was calculated using the “psych” package (Revelle, 2017). This  
13 analysis revealed that the minimum split-half reliability was .47, the mean split-half reliability  
14 was .48 and the maximum split-half reliability was .63. Our measure appears at least as reliable  
15 as Kaufman et al.'s (i.e., .44), and possibly better. We also used standardized Cronbach's alpha,  
16 and its value was quite similar to the value for split-half reliability (i.e., .53).

17 *3.2. Types of expressions in metaphor processing task.*

18 To test the hypothesis that the meaning decision task should be sensitive to the difference  
19 in processing between literal and metaphorical expressions, we computed a linear mixed model  
20 on RTs with the Type of expression (3 levels: literal, metaphorical, meaningless) as a within-  
21 participant variable (i.e., crossed variable), which was complemented by an ANOVA on trimmed  
22 means due to the asymmetry of the residual distribution. This analysis revealed a significant

1 effect of Type of expression, both for the linear mixed effects estimation,  $F(2,168) = 39.35, p <$   
2  $.001$ , and for the trimmed mean ANOVA,  $F(1.5, 75.17) = 33.00, p < .001$ .

3 Orthogonal planned comparisons revealed that the expressions correctly classified as  
4 meaningful (i.e., literal and metaphorical) were processed faster than the meaningless ones,  
5  $t(168) = 7.77, p < .001, r^2 = .26$ . Moreover, literal expressions were processed faster than  
6 metaphorical ones,  $t(168) = 4.28, p < .001, r^2 = 0.10$  (Figure 2).

7 -----  
8 INSERT FIGURE 2 ABOUT HERE  
9 -----

10 The fact that metaphorical expressions were processed slower than literal expressions and  
11 faster than meaningless expressions makes it relevant to compute indices to assess participants'  
12 ease in understanding metaphors. In accordance with Le Ny and Franquart-Declercq's (2002)  
13 work, these two indices were formulated within the framework of general models of language  
14 comprehension and based on the incremental nature of language comprehension. According to  
15 this view, semantic representations of verbs contain knowledge of the participants involved in the  
16 situation described by the verb (Ferretti, McRae, & Hatherell, 2001; McRae, Ferretti, & Amyote,  
17 1997). For instance, people know that a typical patient of the verb *assassinate* is a human being.  
18 This knowledge is used to pre-activate the salient semantic features of the verb's typical agents  
19 and patients. The meaning of each incoming word is supposed to be incorporated, as soon as it is  
20 encountered, into the representation of the statement that is under construction. As a result, this  
21 representation is gradually adapted and progressively refined, taking into account the meaning of  
22 each word and its context. In this regard, a non-conventional metaphor expresses an innovative  
23 meaning: metaphor comprehension should involve the activation of the non-salient features of

1 words that are appropriate in the context of the metaphor. Finally, when none of the features of  
2 the words in question are appropriate, no meaning can be found. Thus, some verb patients are  
3 easily accepted, given that it is likely that their features are pre-activated (i.e., a process of  
4 meaning retrieval for literal expressions); unusual patients may be accepted if non-salient  
5 features can be activated (i.e., a process of sense creation for metaphorical expressions); and  
6 some patients are considered as impossible because even their non-salient features are  
7 inappropriate, as is the case for our meaningless expressions. In other words, each of the three  
8 conditions represents a different level of acceptability on the continuum of patient acceptability  
9 described by Le Ny and Franquart-Declercq (2002).

10 Since adults are sensitive to very small probabilistic differences (e.g., in the context of  
11 mapping new word–object pairs; Vouloumanos, 2008), metaphorical expressions should be  
12 considered as much less probable than literal ones but should be much more probable than  
13 meaningless ones. Differences in RTs should be larger for participants who are more sensitive to  
14 probabilistic regularities, that is, participants with better implicit learning abilities. This  
15 hypothesis can be tested by calculating two indices on the correctly classified expressions. The  
16 first index (Index 1) was calculated as follows:  $\frac{RT_{metaphorical} - RT_{literal}}{mean RT}$ . The second index (Index  
17 2) was computed as  $\frac{RT_{meaningless} - RT_{metaphorical}}{mean RT}$ . For both these indices, the difference between  
18 conditions was divided by the mean RTs of the three conditions (considered as the baseline) in  
19 order to control for differences in individuals' processing speed.

### 20 3.3. *Implicit learning abilities in the understanding of metaphors*

21 To determine the impact of implicit learning abilities in finding meanings for  
22 metaphorical expressions, we executed two multiple regression analyses. In the first analysis, the  
23 dependent variable was Index 1 and independent variables were the implicit learning index and

1 the Mill Hill vocabulary score (to control for vocabulary knowledge, which could help in finding  
2 meaning). Multinormality was violated, so we used robust statistics (i.e., bias-corrected and  
3 accelerated (BCA) bootstrapping). This analysis revealed that the slope of the implicit learning  
4 abilities index was positive and significantly different from 0. This model explains 11% of the  
5 variance,  $F(2,82) = 4.99, p = .009$ . The impact of each variable is presented in Table 2.

6 -----  
7 INSERT TABLE 2 ABOUT HERE  
8 -----

9 This analysis suggests that the RT interval between the literal and metaphorical  
10 conditions increases for individuals with higher implicit learning abilities.

11 We performed the same analysis with Index 2, revealing that the slope of the implicit  
12 learning abilities index was negative and significantly different from 0. This model explains 6 %  
13 of the variance,  $F(2,82) = 2.66, p = .076$ . The impact of each variable is presented in Table 3.

14 -----  
15 INSERT TABLE 3 ABOUT HERE  
16 -----

17 This analysis shows that the RT interval between the metaphorical and meaningless  
18 conditions decreases for individuals with higher implicit learning abilities.

19 *3.4. Supplementary analysis*

20 Given that, contrary to our hypothesis, the regression coefficient for implicit learning  
21 abilities is negative, we performed exploratory analyses to determine whether this index was  
22 influenced most by the processing time for metaphorical or for meaningless expressions. More  
23 specifically, if one postulates that processing time for meaningless expressions does not vary and

1 that processing time for metaphorical expressions does vary, the correlation between Index 2 and  
2 the metaphorical condition would be 1. This correlation could be interpreted as showing that  
3 individuals with lower values for Index 2 find it difficult to make sense of metaphorical  
4 expressions, while individuals with higher values can quite easily find some meaning for  
5 metaphorical expressions. Conversely, if one postulates that processing time for meaningless  
6 expressions varies and that processing time for metaphorical expressions does not, the  
7 correlation between Index 2 and the meaningless condition would be 1. In that case, individuals  
8 with higher values for Index 2 have more difficulties rejecting meaningless expressions than  
9 individuals with lower values. Obviously, both postulates are unlikely and the reality is likely to  
10 be between these extremes. Nevertheless, it is possible to determine whether one aspect (i.e.,  
11 ease of finding a meaning for metaphors or difficulties rejecting meaningless expressions) is  
12 predominant by comparing the two correlations. To determine which condition was more  
13 associated with Index 2 (i.e., time cost of meaning creation or ease of rejecting meaningless  
14 expressions), we performed two correlation analyses: one between Index 2 and RTs for the  
15 metaphorical condition and one between Index 2 and RTs for the meaningless condition. When  
16 normality was respected, the Bravais-Pearson coefficient is reported, while Spearman's rho is  
17 used when normality was violated. The first analysis explored the correlation between the time  
18 required in the metaphorical condition and Index 2. It revealed that metaphor processing was  
19 negatively correlated with Index 2,  $\rho = -.347, p = .001$ . The second analysis explored the  
20 correlation between the time required in the meaningless condition and Index 2; this analysis  
21 revealed a significant positive correlation,  $r = 0.60, p < .001$ .

22 As expected, both conditions were correlated with Index 2. In order to determine which  
23 view is more likely (i.e., time cost of meaning creation or ease of rejecting meaningless

1 expressions), we compared the values of both correlations with the absolute value. It appears that  
2 Index 2 is more associated with the meaningless condition than with the metaphorical condition,  
3  $z = 2.12, p = .03$ , suggesting that larger values of Index 2 can most likely be attributed  
4 difficulties rejecting meaningless expressions.

5         These three supplementary analyses remain significant even after a Holm correction of  
6 probability.

#### 7 **4. Discussion**

8         Although metaphors are a fundamental part of language and are widely used to  
9 conceptualize complex ideas (Lai, 2008), little is known about the fundamental processes that  
10 influence metaphor comprehension. Several studies have suggested that implicit learning  
11 abilities may be involved in the understanding of novel metaphors (Kaufman et al., 2010; Li et  
12 al., 2013; Zhao et al., 2011). Thus, we hypothesized that, beyond the role of implicit learning  
13 abilities on syntax (Thompson & Newport, 2007), word acquisition (e.g., Vouloumanos, 2008),  
14 second language learning (Pajak et al., 2016) and even comprehension of literal language  
15 (Misyak & Christiansen, 2012), they could play a more specific role in metaphor understanding.  
16 Although this question was addressed in Li et al.'s (2013) study, we noted several limitations of  
17 that study; in particular, the measure of implicit learning could be questioned and it was not clear  
18 whether implicit learning mechanisms were involved in the creation or in the understanding of  
19 metaphors. To get around these limitations, we followed and attempted to improve on Kaufman  
20 et al.'s (2010) suggestion that a reliable measure should be used to assess implicit learning  
21 abilities, and used a meaning decision task to explore metaphors.

22         Concerning the measure of implicit learning abilities, although Kaufman et al.'s (2010)  
23 measure was reliable, it could be claimed to lack sensitivity. Our measure – the number of

1 probable items that were processed significantly faster than the improbable ones (i.e., RTs  
2 inferior to the fastest 5% of the improbable items) – appears as reliable as Kaufman et al.’s, but  
3 we believe it to be more sensitive. Nevertheless, our study does not allow us to assess the test-  
4 retest reliability, which can be weak for the SRT task (Siegelman & Frost, 2015). This question  
5 should be addressed in future studies.

6         In the meaning decision task, we showed a gradient of increasing processing time from  
7 literal expressions to metaphors and finally to meaningless expressions. This result is in  
8 accordance with Le Ny and Franquart-Declercq’s (2002) view of the semantic congruence  
9 hypothesis. In their view, the processing of a verb automatically activates congruent patients,  
10 which facilitates decisions regarding the meaning of the verb + patient expression. Since patients  
11 in literal expressions present the highest probability of activation, their processing should be  
12 facilitated in comparison to the novel metaphor expressions, which explains why metaphorical  
13 expressions are processed slower than literal ones. Similarly, given that the patients in the  
14 meaningless expressions are improbable, they are not activated by the verb and more time is  
15 required for their processing.

16         The presence of this gradient made it relevant to explore the processes involved in the  
17 comprehension of metaphors. Our results showed that individuals with better implicit learning  
18 abilities presented larger time intervals between the RTs for literal and metaphorical expressions.  
19 This result is consistent with our hypothesis that individuals with better implicit learning would  
20 create more and stronger associations in their semantic networks. Indeed, implicit learning  
21 abilities are involved in semantic richness (Rabovsky et al., 2012), which would allow literal  
22 expressions to be processed very quickly by automatic spreading activation processes.  
23 Conversely, when participants have to find a meaning for a metaphorical expression, this kind of

1 meaning retrieval is not possible given that we used novel metaphors. Thus, participants with  
2 richer semantic networks may have had to explore and reject more possible meanings than  
3 individuals with less rich semantic networks; as a result, the former required more processing  
4 time. This explanation can also be applied to the meaningless condition since the patients in  
5 these expressions did not match any of the possible patients activated by the verb. Our  
6 interpretation is coherent with the suggestion that language abilities can be predicted by inter-  
7 individual differences in implicit learning, and more specifically with Rabovsky et al.'s (2012)  
8 view that implicit learning and semantic richness are associated. Our interpretation, whereby  
9 inter-individual differences in implicit learning are involved in language proficiency, could be  
10 quite easily tested by determining whether individuals with larger semantic priming effects also  
11 have enhanced implicit learning abilities. Moreover, if a link between semantic priming and the  
12 comprehension of metaphors is observed, it would give more support to the semantic congruity  
13 hypothesis.

14 We suggested that Index 2 (i.e., the difference between the metaphorical and meaningless  
15 conditions) could reflect the probabilistic continuum of acceptability between an unusual but  
16 acceptable and an extremely unlikely patient. For the unusual acceptable patient, a sense can be  
17 created by activating non-salient features of the words, while this is almost impossible for the  
18 extremely unlikely patient. Given that individuals are highly sensitive to probabilistic constraints  
19 of language, participants with greater implicit learning abilities should find it easier to identify  
20 that metaphorical patients are more probable than meaningless ones (leading to larger values for  
21 Index 2). Contrary to our hypothesis, though, the slope between Index 2 and implicit learning  
22 abilities was negative, which means that the RT differential between the metaphorical and  
23 meaningless expressions was shorter for individuals with higher implicit learning abilities. This

1 result can be interpreted in light of Benau et al.'s (2011) finding that semantic incongruities are  
2 processed fast (see also Kutas & Hillyard, 1980). Similarly, Glucksberg et al. (1982) observed  
3 that, when participants were asked to reject incorrect literal sentences, they were slower to reject  
4 sentences for which a metaphorical sense could be found (e.g., "some jobs are jails") than  
5 sentences for which it was not possible to find a metaphorical meaning (e.g., "some roads are  
6 jails"). The correlations indicate that the size of Index 2 depends more on the time needed to  
7 decide that an expression in the meaningless condition does not have any sense than on the time  
8 to decide that an expression in the metaphorical condition could have a meaning. Thus, people  
9 with higher implicit learning abilities tend to process semantic incongruity more efficiently, and  
10 the role of implicit learning abilities may be directly related not to the comprehension of  
11 metaphors but rather to the intuition that it is or is not possible to find a meaning for an  
12 expression. Thus, it looks as if participants with higher implicit learning abilities are more  
13 sensitive to the certitude that the patient is an impossible one, which means that the level of  
14 certitude is equally high for a probability of 1 than for a probability of 0 that an event can occur  
15 and reach a minimum when probability is 0.5. This view is coherent with Benau et al.'s (2011)  
16 finding that semantic incongruities are processed fast (see also Kutas & Hillyard, 1980). In other  
17 words, participants with higher implicit learning abilities may be more efficient at distinguishing  
18 between expressions with no meaning and expressions with a meaning, even if the meaning is  
19 not easily processed (as in novel metaphorical expressions). Our interpretation is close to Bolte  
20 and Goschke's (2005) view that semantically coherent sentences are processed automatically and  
21 depend on the intervention of implicit and associative processes.

22 The results of our study also seem coherent with the neuroanatomical and  
23 pathophysiological literature. Implicit learning is partly sustained by the basal ganglia (Meier et

1 al., 2013; Wilkinson, Khan, & Jahanshahi, 2009), which may also be involved in metaphor  
2 processing (Uchiyama et al., 2012). Indeed, Copland (2003) showed that people suffering from a  
3 basal ganglia lesion were impaired at processing ambiguous sentences. Given that metaphors can  
4 be seen as ambiguous sentences because they can possess two different meanings (i.e., the literal  
5 and the metaphorical one), their processing should also be sustained by the basal ganglia.  
6 Moreover, according to Chenery, Angwin, and Copland (2008), the basal ganglia may facilitate  
7 and/or suppress different meanings relative to a context in which there are lexical ambiguities,  
8 which recalls the suppression mechanism posited to be involved in the comprehension of  
9 nominal metaphors (Fernández, 2007). Finally, Sato, Schafer, and Bergen (2015) pointed out that  
10 understanding metaphors may rely partly on the activation of cerebral area dedicated to  
11 sensorimotor control (i.e., the basal ganglia). Nevertheless, to date, no study has tried to establish  
12 a possible connection between the cerebral areas involved in metaphor processing and implicit  
13 learning, and further studies should be conducted to explore this possibility. For instance, the  
14 investigation of populations with lesions in the basal ganglia, such as patients with Parkinson's  
15 disease or Huntington's chorea (Wilkinson et al., 2009; Willingham & Koroshetz, 1993), could  
16 provide further evidence about the relationships between implicit learning abilities and metaphor  
17 comprehension. This study provides additional evidence that implicit learning abilities affects  
18 even the highest level processes of language. Our results also have some implications for  
19 populations suffering from language impairments, such as children with specific language  
20 impairment (SLI). Indeed, it has been shown that these children present lower implicit  
21 procedural learning abilities (e.g., Ullman & Pierpont, 2005; Lum, Gelgic & Conti-Ramsden,  
22 2010; Gabriel et al., 2013). Thus, considering the results of the present study, one could

1 hypothesize that children with SLI might have some difficulties understanding metaphors. This  
2 question remains to be addressed.

3         One key limitation on the current study is the fact that it does not allow us to determine  
4 whether the meanings attributed to the metaphors are qualitatively better for participants with  
5 higher implicit learning abilities than for those with weaker abilities. Further studies should  
6 explore this issue.

## 7 **5. Conclusions**

8         This study aimed to explore the involvement of implicit processes in metaphor  
9 processing. Our results corroborate Li et al.'s (2013) findings with a more robust and reliable  
10 measure of implicit learning: implicit learning abilities are involved in the understanding of  
11 metaphors. Our results are also coherent with Kaufman et al.'s (2010) study. Our study opens up  
12 new research perspectives, especially in the exploration of the link between semantic priming  
13 processes and metaphor processing, and of spreading activation mechanisms, and could have  
14 implications for the identification of difficulties in SLI patients.

## 15 **Acknowledgements**

16 This study was supported by the University of Reims Champagne-Ardenne. We would like to  
17 thank two anonymous reviewers, whose comments and suggestions have been extremely helpful  
18 in revising the manuscript.

19

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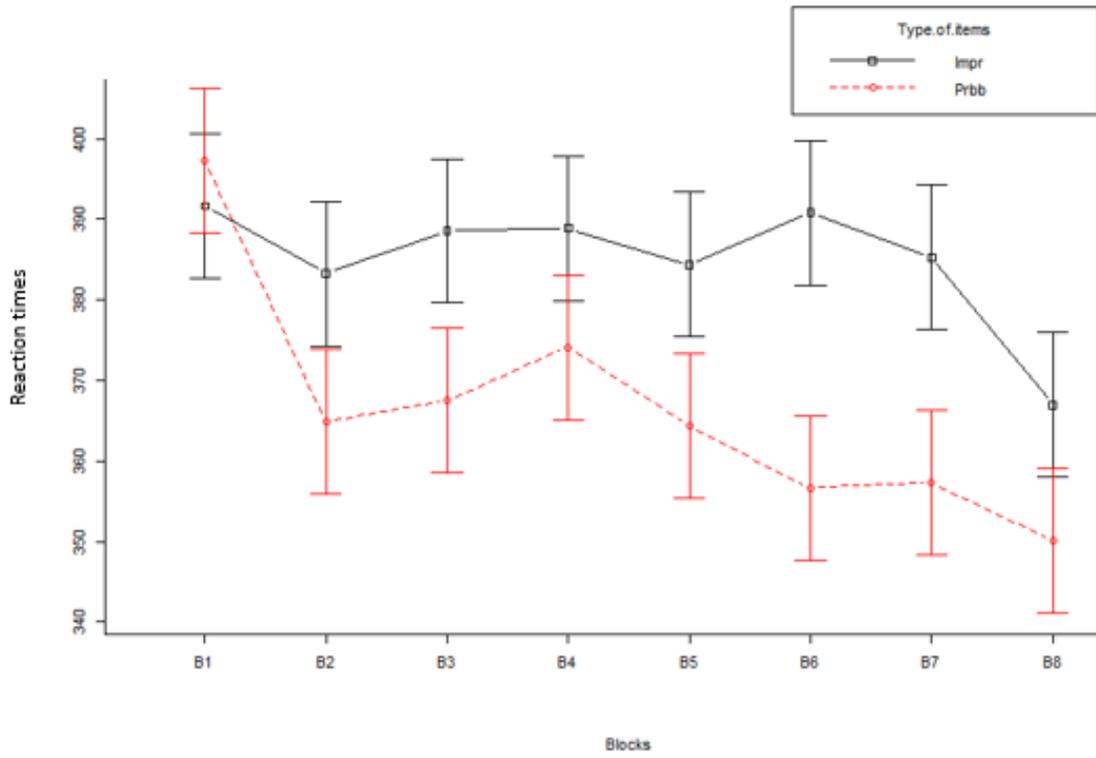
1 **Figure captions**

2 Figure 1: Mean RTs (milliseconds) depending on the type of sequence (improbable vs. probable)  
3 and the type of block (1 to 8).

4 Figure 2: Mean RTs (milliseconds) depending on the type of expression (literal vs. metaphorical  
5 vs. meaningless).

6

1 Figure 1.



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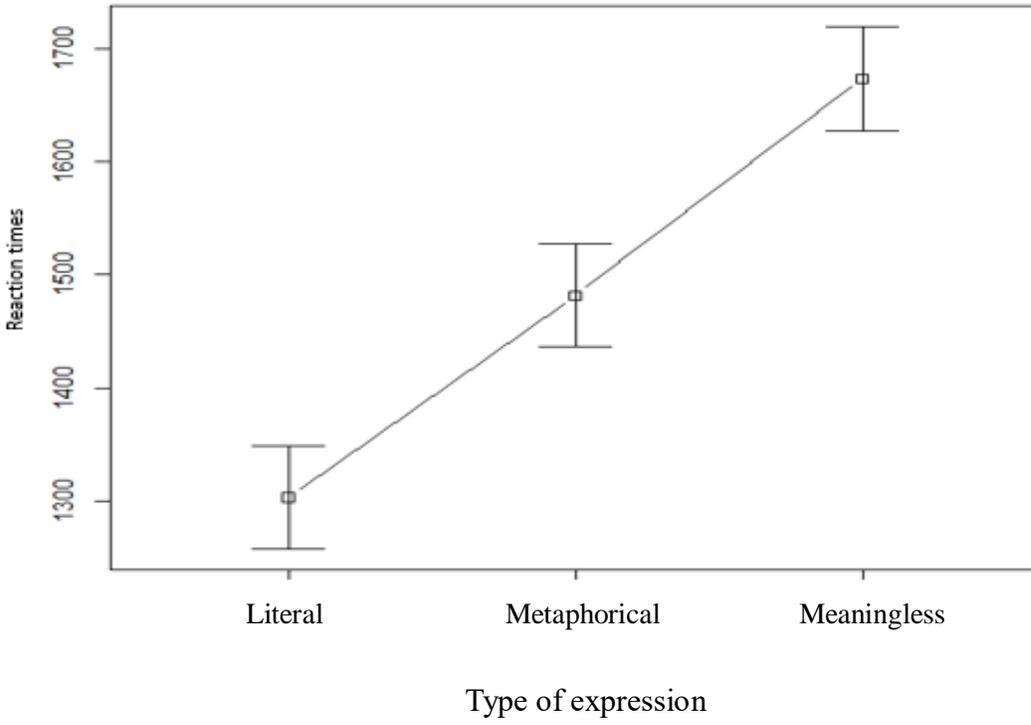
1 **Figure 2.**

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1 Table 1. Mean (and SD) for the different types of expressions.

	Literal	Metaphorical	Meaningless
Familiarity	4.78 (0.69)	3.44 (0.6)	1.69 (0.39)
Difficulty	2.03 (0.65)	2.7 (0.71)	4.6 (0.58)
Imagery	3.6 (1.15)	2.94 (0.68)	1.16 (0.19)

2

1 Table 2. Regression coefficient (and confidence interval estimated by bias-corrected and  
 2 accelerated bootstrapping) for the effect of implicit learning abilities and Mill Hill vocabulary  
 3 score on Index 1 (semantic richness).

Variable	b (BCA bootstrap CI)	$\beta$	t	p	$\Delta R^2$
Implicit learning	0.002 (0.001, 0.003)	0.314	3.006	.004	0.094
Mill Hill	0.005 (-0.003, 0.012)	0.122	1.172	.245	0.015

4

5

1 Table 3. Regression coefficient (and confidence interval estimated by bias-corrected and  
 2 accelerated bootstrapping) for the effect of implicit learning abilities and Mill Hill vocabulary  
 3 score on Index 2 (sense creation).

Variable	b (95% bootstrap CI)	$\beta$	t	p	$\Delta R^2$
Implicit learning	-0.003 (-0.007, -0.0001)	-0.23	-2.15	.035	0.056
Mill Hill	0.005 (-0.010, 0.022)	0.072	0.672	.503	0.005

4