Journal of Cognitive Psychology
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/pecp21

Counterfactual sentences activate embodied meaning: An action-sentence compatibility effect study

Manuel de Vega [a] & Mabel Urrutia [a]
[a] University of La Laguna , Canary Islands, Spain
Published online: 07 Oct 2011.

To cite this article: Manuel de Vega & Mabel Urrutia (2011) Counterfactual sentences activate embodied meaning: An action-sentence compatibility effect study, Journal of Cognitive Psychology, 23:8, 962-973, DOI: 10.1080/20445911.2011.590471

To link to this article: http://dx.doi.org/10.1080/20445911.2011.590471

JOURNAL OF COGNITIVE PSYCHOLOGY, 2011, 23 (8), 962–973

Psychology Press
Taylor & Francis Group

Counterfactual sentences activate embodied meaning: An action–sentence compatibility effect study

Manuel de Vega[1] and Mabel Urrutia[1]

[1]University of La Laguna, Canary Islands, Spain

Recent evidence suggests that understanding factual action-related sentences involves embodied simulations. But, what happens with counterfactual sentences that describe hypothetical events in the past? This study demonstrates that even in this case embodied simulations of actions take place. Participants listened to factual or counterfactual sentences describing a transfer away from or towards them. After the transfer verb (e.g., gave) was received, either a motion cue (Exp. 1) or a static cue (Exp. 2) prompted participants to move their finger towards or away from them to press a button. Finger motion was initially interfered with in cases involving a concurrent matching sentence (e.g., transfer away-motion away), suggesting that counterfactual meaning involves a motor simulation or ''resonance''. The temporal course of this resonance differs slightly between factual and counterfactual sentences.

Keywords: Action–sentence compatibility effect; Comprehension; Counterfactuals; Embodiment.

People not only communicate factual information, they are also capable of producing and understanding counterfactual sentences like ''If Mary had bought that lottery ticket, she would have won a prize worth millions''. These sentences involve a sort of semantic dead end: They describe a sequence of events in the past or in a parallel world that never occurred. Their psychological functions in reasoning, causal attribution, or emotion activation have been described elsewhere (e.g., Byrne, 2005; Roese, 2005).

From a semantic perspective, counterfactuals seem to involve a dual meaning. Thus, understanding the counterfactual example above involves the representation of two possible states of the world: A ''real'' situation in which Mary did not buy the ticket or win the lottery (not-p & not-q), and a situation in which Mary bought the ticket and won the lottery (p & q). The notion of dual meaning in counterfactuals has been empirically investigated by psychologists of reasoning (e.g., Byrne, 2005; Kahneman & Tversky, 1982; Thompson & Byrne, 2002). Most of these studies used offline methods in which participants first read a factual conditional (e.g., ''If Mike went to Calgary, then Barbara went to Edmonton'') or a counterfactual conditional (e.g., ''If Mike had gone to Calgary, then Barbara would have gone to Edmonton''), and were then asked to choose from among several sentences those which were more consistent with or were implied by the conditional sentence's meaning. The results typically confirm that participants tend to exclusively choose a factual interpretation (p & q) for factual conditionals, but they choose both factual (p & q) and negation (not-p & not-q) for counterfactual conditionals. Moreover, moving beyond this choice-task methodology, Santamaría, Espino,

Correspondence should be addressed to Manuel de Vega, Facultad de Psicología, Campus de Guajara, 38205 La Laguna, Canary Islands, Spain. E-mail: mdevega@ull.es

This research was supported by the Spanish Ministry of Science and Innovation (Grant SEJ2007-66916), the Canary Agency for Research, Innovation and Information Society (Project NEUROCOG), and the European Regional Development Fund to MDV. We are grateful to Victor Romeo and Yurena Morera for their help in programming the experiments in E-Prime, and analysing the data, respectively.

http://www.psypress.com/ecp http://dx.doi.org/10.1080/20445911.2011.590471

and Byrne (2005) gave participants counterfactual conditionals such as ''If there had been roses then there would have been lilies'' as primes to understand target sentences like ''There were roses and there were lilies'' or ''There were no roses and there were no lilies''. The same procedure was used with factual conditional primes such as ''If there are roses, there are lilies''. When target reading times were collected, factual sentences primed only the affirmative target ''There were roses and there were lilies'', whereas counterfactual sentences primed both the affirmative and the negative targets, suggesting that readers had generated a double representation.

Only recently have researchers in language comprehension paid attention to counterfactuals, exploring the temporal course of their dual meaning activation (de Vega, Urrutia, & Riffo, 2007; Ferguson & Sanford, 2008; Stewart, Haigh, & Kidd, 2009; Urrutia, de Vega, & Bastiaansen, 2011). Thus, de Vega et al. (2007) presented readers with short stories describing a factual state in the first paragraph, followed by additional information that was either factual or counterfactual. For instance:

1. Initial situation: John was still in the office sitting in front of the computer. He started to *type* a report that his boss had asked him for.
2. Factual continuation: Because he had enough time, he went to the café to *drink* a beer.
3. Counterfactual continuation**:** If he had had enough time, he would have gone to the café to *drink* a beer.

After reading the story, participants were asked to verify a test probe that either belonged to the beginning of the story (*type*), or to the subordinate clause shared by the factual and counterfactual version of the story (*drink*). Immediately after reading the critical sentence (2 or 2′), readers verified the first test probe more slowly in the factual stories than in the counterfactual stories, whereas they verified the second probe equally rapidly in both types of stories. The interpretation of these results is quite straightforward. In the factual stories, the situation model is updated and the attention focus moves on to the new factual content, whereas in the counterfactual version, updating is cancelled and the attention focus goes back to the initial factual information. However, the new information conveyed by the counterfactual sentence is also accessible for a while, clearly indicating that its alternative meaning (p & q) is also represented.

In the same vein, Ferguson and Sanford (2008) used the eye-movement technique to demonstrate that, after reading a counterfactual sentence conflicting with real-world knowledge, participants cannot avoid representing the real-world situation. In their study, Ferguson and Sanford used conditional sentences either with a counterfactual (''If cats were vegetarians they would be cheaper for owners to look after''), or a factual meaning (''If cats are hungry they usually pester their owners until they get fed''). Immediately after reading one of these conditional sentences, participants received a continuation sentence consistent with their real-world knowledge (''Families could feed their cat a bowl of fish and it would gobble it down happily''), or consistent with the counterfactual world (''Families could feed their cat a bowl of carrots and it would gobble it down happily''). In spite of the fact that the counterfactual sentence establishes a hypothetical scenario in which cats are vegetarians, participants do not immediately suppress their real-world knowledge. Thus, the first-pass reading time—a measure of initial cognitive load—for real-world continuation showed a similarly slow reading after the counterfactual context (which provided a consistent setting) as after the real-world context. In other words, real-world violations were not neutralised by a counterfactual context.

In sum, theoretical proposals, offline data, and online data converge to show that readers of counterfactual sentences activate, at least momentarily, a realistic scenario in which the counterfactual events did not occur, and an alternative scenario that considers the counterfactual events ''as if'' they had happened. This paper goes one step further, exploring how the meanings of counterfactuals are represented. Specifically, does the ''as if'' meaning involve embodied simulations of actions, or merely a disembodied symbolic representation? Briefly, the symbolist approach assumes that the meaning of words consists of mental symbols, which are abstract, arbitrary, and amodal. For instance, the word ''cat'' would activate an abstract symbol in your mind, which is connected to other equally abstract symbols, none of which have any similarity to your visual, auditory, tactile, or motor experience of cats. By contrast, the embodiment approach to meaning considers that language is grounded in the world (see de Vega, Glenberg, & Graesser,

2008, for a debate between the two approaches). According to the embodiment view, meaning consists of mental simulations of the objects, events and situations to which words refer (e.g., Barsalou, Santos, Simmons, & Wilson, 2008; Glenberg & Kaschak, 2002; Pulvermüller, Hauk, Nikulin, & Ilmoniemi, 2005; Taylor & Zwaan, 2008, 2009). For instance, the word ''grasping'' could briefly activate in your mind a motor simulation of the grasping action. A plausible neuronal mechanism for embodied meaning is motor resonance; that is, the partial reactivation of the motor cortex elicited by action-related words (Taylor & Zwaan, 2008, 2009; Zwaan & Taylor, 2006). Mixed approaches also exist, which assume that both shallow linguistic representations and/or deeper embodied representations could be activated by action-related language (e.g., Barsalou et al., 2008; Taylor & Zwaan, 2009). These mixed approaches are relevant here. Thus, it might be possible that factual sentences elicit embodied representations as demonstrated elsewhere, whereas counterfactuals, given their hypothetical character, would not activate any motor event.

Recently, an intriguing phenomenon has provided support for theories of embodied cognition: the interaction between language comprehension and action. While understanding sentences describing motor events, participants were asked to perform a motor task designed to match or mismatch the meaning of the sentences. In some cases, a facilitating Action–sentence Compatibility Effect (ACE) was reported; that is, the meaning–action matching conditions produced faster responses than the mismatching conditions (Borreggine & Kaschak, 2006; Glenberg & Kaschak, 2002; Kaschak & Borreggine, 2008; Santana & de Vega, 2011; Zwaan & Taylor, 2006). Thus, Glenberg and Kaschak (2002) asked people to judge the sense of sentences describing a transfer motion towards or away from them (e.g., ''Andy delivered the pizza to you'' or ''You delivered the pizza to Andy'') or of nonsense sentences. For some participants, the ''yes'' response involved a hand motion towards their body, and the ''no'' response involved a motion away from their body; for other participants, it was the other way around. The judgement time for sensible sentences was faster for the matching conditions (e.g., sentences describing a transfer towards the person, responding ''yes'' towards the person) than for the mismatching conditions. Other studies have found interfering rather than facilitating ACE for the matching conditions (Boulenger et al., 2006; Buccino et al., 2005; de Vega, Moreno, & Castillo, 2011). For instance, Buccino et al. (2005) gave participants hand-action sentences (e.g., ''He took the cup''), foot-action sentences (e.g., ''He kicked the ball''), or abstract sentences, and they were to give a response only if the sentence described an action, and refrain from responding otherwise. Hand responses were faster for foot-action than hand-action sentences, and foot responses were faster for hand-action than foot-action sentences.

Several factors could contribute to the discrepancy in the ACE results. The experiments differ in the complexity of the linguistic materials (single words, single-clause sentences, or double-clause sentences), the semantic task (sensibility judgements, categorical judgements, lexical decision), the response paradigm (choice, go/no-go, self-paced reading), and the temporal overlap between the linguistic stimulus and the motor response. Concerning the latter issue, de Vega et al. (2011) manipulated the temporal overlap between the comprehension process and the production of the motor response. The motor action accompanying the transfer sentences was a simple directional response to an apparent motion cue. This psychophysical response does not require the burden of a semantic judgement; and the apparent motion cue could be placed at specific times in the sentence without the need to process the whole sentence. De Vega et al. used transfer sentences, and collected the motor responses at several intervals following the transfer verb, rather than at the end of the sentence. For short verb–action intervals (100–200 ms) they found interference in the matching conditions, whereas when the motion cue was given 350 ms after the verb onset, there was facilitation in the matching conditions, indicating priming between meaning and action. The early interference could be consequence of the competition for motor cortex resources between language-based motor ''resonance'' and action performance. In other words, understanding action-related sentences would partially activate the same motor regions as performing actions. This claim is consistent with neurological evidence that demonstrates that neural resonance of sensory-motor areas reach maximum peak 200 ms after action verbs onset (Pulvermüller et al., 2005).

This research uses the aforementioned paradigm to analyse whether counterfactual sentences describing transfer events produce similar

interfering or facilitating ACE to their factual counterparts. The rationale is that the "as if" meaning of counterfactuals is similar to a factual meaning. Therefore, understanding action-related counterfactuals may trigger a simulation of the actions or a motor resonance resulting in observable ACE. Another possibility is that, unlike factual sentences, counterfactuals do not activate any embodied representation and, consequently, ACE would not be observed. This might occur if the two alternative meanings of the counterfactual ("not-p & not-q" and "p & q") are represented in a relatively shallow (e.g., propositional) format, without the need to activate any motor representation (Barsalou et al., 2008; Taylor & Zwaan, 2009). Experiment 1 manipulated the interval between the transfer verb onset and the motion cue (100 or 200 ms). With these short intervals we expect to replicate both with factual and counterfactual sentences the interference pattern in the matching conditions previously reported with factual sentences, and which is considered a marker of automatic resonance processes (de Vega et al., 2011). In addition, Experiment 2 was run as a control task in which a static cue (a colour change) substituted the visual motion cue. If the ACE were observed even without the presence of a motion cue, then this could only be attributed to the participant's motor response alone and not to the perceptual processing of the visual motion cue.

EXPERIMENT 1

Method

Participants. Ninety-four students of Psychology (including 74 women) from the University of La Laguna received credits for their voluntary participation in the experiment. All were native speakers of Spanish.

Materials. Ninety-six two-clause sentences were created, each of which was preceded by a one-word title. The first clause introduced the agent of the transfer event, and the second clause described the transfer action away from or towards the agent. A factual and a counterfactual version of each sentence were written (see Table 1), sharing the same critical word in which the ACE was tested (the past participle "prestado" in one example of Table 1). Factuals and counterfactuals differ in syntactic structure, mood, and tense (both in Spanish and English). A stricter matching between structures would have been accomplished by using a conditional form in factuals (e.g., "If my brother was generous he lent me the Harry Potter novel without hesitation"), rather than the causal construction employed here. However, the Spanish conditional (e.g., "Si mi hermano fuera generoso me prestaría la novela de Harry Potter") expresses a wish or intention rather than a factual event, and the critical word differs in the counterfactual and factual (e.g., "prestado" vs. "prestaría", respectively). Notice that the agent in the sentences was described in the first person (I, me), although the details of the situations were fictitious (e.g., a specific participant might not have a brother, or might not be interested in reading Harry Potter). In spite of this, we expect that the participants take the agent's perspective to understand the transfer events, as previous ACE's experiments have shown (Glenberg & Kaschak, 2002). Given the relative freedom of Spanish word order, it was possible to construct the sentences such that the transferred object and the direction of the transfer were mentioned before the transfer verb. Eight training sentences and an additional set of 48 filler sentences (24 factual and 24 counterfactual) using nontransfer verbs (e.g., knowing, remembering, etc.) were also included.

Procedure and design. A computer keyboard was modified to meet the needs of the experiment. The function keys on the right part of the keyboard were removed, except for K5, K2, and K8, which were assigned as the resting-key, the towards-key and the away-key, respectively, as illustrated in Figure 1A. The structure of each trial, illustrated in Figure 1B, was as follows: The trial started with the word "DIANA" (TARGET) presented auditorily as a prompt to press the resting key. Then, two convergent lines resembling a road in perspective appeared on the screen, and immediately afterwards, the sentence was presented auditorily, except for the transfer verb. Immediately after finishing the last spoken word, the transfer verb was presented visually in the middle of the screen within the "road", remaining still on the screen for either 100 or 200 ms, and then apparently "jumped" away from or towards the participant according to the animation sequence shown in Figure 1B. This apparent motion was a cue for the participants to release the resting-key and move their hand in the

TABLE 1

Experiments 1 and 2: Examples of materials in Spanish and the approximate translation to English (the word order was normalised to make the English version grammatical)

Towards me	Factual	Novela. Como mi hermano es generoso la novela de Harry Potter me la ha *prestado* sin vacilar (Novel. Given that my brother is generous he has *lent* me the Harry Potter novel without hesitation)
	Counterfactual	Novela. Si mi hermano hubiese sido generoso, la novela de Harry Potter me la habría *prestado* sin vacilar (Novel. If my brother had been generous he would have *lent* me the Harry Potter novel without hesitation)
	Probe	Hermano [Brother]
	Question	¿Me ha prestado mi hermano El señor de los anillos? [Has my brother lent me The Lord of the Rings?]
Away from me	Factual	Baloncesto. Como en ese momento yo estaba lejos de la canasta, el balón se lo he *pasado* a otro jugador Basketball. Given that I was far away from the basket at that moment I've *passed* the ball to another player
	Counterfactual	Baloncesto. Si en ese momento yo hubiera estado lejos de la canasta, el balón se lo habría *pasado* a otro jugador Basketball. If I had been far away from the basket in that moment I would have *passed* the ball to another player
	Probe	gol [goal]

same direction to press the corresponding away- or towards-key. Five hundred milliseconds after the keypress response, the end of sentence was presented auditorily. At the offset of the auditory sentence, participants were given a visual word probe and asked to decide whether or not it had appeared in the sentence. They used their left hand middle and index fingers to press the yes/no response keys (numbers 1 and 2 on the keyboard), respectively. Finally, in 30% of trials, there was a memory question related to the sentence content. Participants were instructed to understand each sentence and perform two tasks speedily: responding to the test probe (and, eventually, to the memory question), and moving their finger to press the away- or towards-key when they were prompted by the visual animation. Then they received eight training sentences, followed by the 96 experimental sentences (12 in each of the eight conditions resulting from crossing sentence type, transfer direction, and motion direction), which were randomly mixed with the 48 filler sentences.

A repeated-measures factorial design was performed: 2 Sentence type (factual/counterfactual) $\times 2$ Transfer direction (away/towards) $\times 2$ Motion direction (away/towards) $\times 2$ Motion

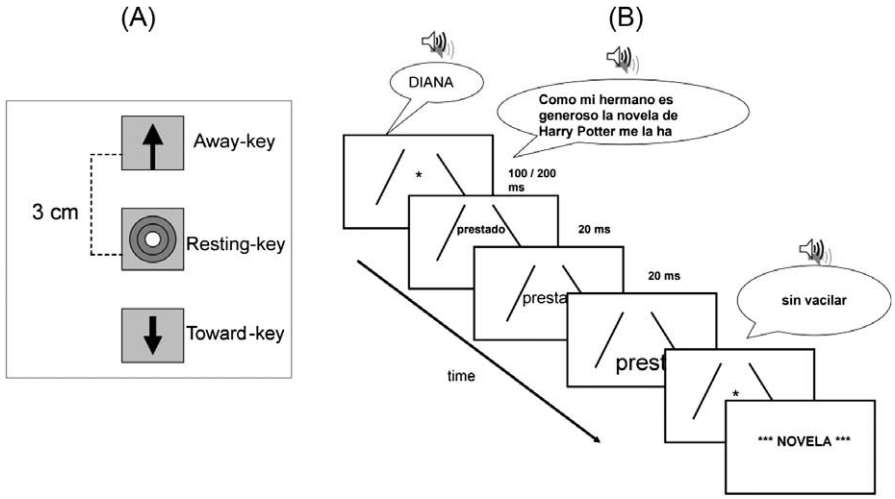

Figure 1. (A) Response keys display for the finger motion task, and (B) temporal sequence of a trial (approximate translation: ''Given that my brother is generous he has lent me the Harry Potter novel without hesitation''/NOVEL). All words were presented auditorily except the transfer verb (prestado/lent) that was presented visually, and ''moved'' away or towards oneself.

delay (100/200 ms). All factors were manipulated within-participants except the delay: Half of the participants were randomly assigned to each motion delay. The motion direction applied to the transfer verbs was counterbalanced among participants. The dependent variables were: (1) the releasing time of the resting-key, (2) the time to press the corresponding direction key, (3) the latency of response for the word probe, (4) the direction response errors, and (5) the probe errors.

Results

Five participants were discarded from the data because of their poor performance in the memory questions (more than 30% errors). Wrong responses either in the motor task (less than 1%), or the probe task (7.5%) were also discarded from the reaction time analyses. We will report only on the results of the key-pressing time and the word probe time, because these were the only dependent measures sensitive to the experimental manipulations.

Key-pressing time

Towards-responses were faster ($M = 228$ ms) than away-responses ($M = 267$ ms), $F(1, 87) = 23$, $MSE = 18830.571$, $p < .0001$. The most important effect, however, was a four-way interaction: Sentence type × Transfer direction × Motion direction × Motion delay, $F(1, 87) = 7.64$, $MSE = 3965.158$, $p < .007$. To interpret this complex interaction, we ran separate analyses for factual and counterfactual sentences:

Factual sentences. A three-way Transfer × Motion × Delay interaction was found, $F(1, 87) = 4.13$, $MSE = 23655.33$, $p < .045$, suggesting that the ACE was qualified by the verb–action temporal overlapping. Specifically, for the 100 ms delay, there was no ACE, Transfer × Motion, $F(1, 44) < 1$, whereas for the 200 ms delay, the ACE was significant, Transfer × Motion, $F(1, 43) = 4.31$, $MSE = 11138.229$, $p < .04$. As Table 2 shows, at this delay matching conditions produced slower responses than mismatching conditions, indicating the presence of interfering ACE.

Counterfactual sentences. Here too, there was a three-way Transfer × Motion × Delay interaction, $F(1, 87) = 3.87$, $MSE = 8517$, $p < .05$. In this case, however, the ACE was only significant for the 100 ms delay, Transfer × Motion, $F(1, 44) = 5.86$, $MSE = 494.363$, $p < .02$; that is, the matching conditions produced slower responses than the mismatching conditions, again indicating the presence of an interfering ACE (Table 2). The pairwise contrasts showed longer latencies for ''away transfer-away motion'' than for ''towards transfer-away motion'', $t(44) = 2.94$, $p < .005$. By contrast, the ACE was not significant for the 200 ms delay, Transfer × Motion, $F(1, 43) = 1.48$, $MSE = 3950.950$, $p = .23$.

Probe reaction times

The only significant effect here for the whole set of data was a main effect of sentence type, $F(1, 87) = 4.16$, $MSE = 7655.164$, $p < .04$. Specifically, probe identification was faster for factual ($M = 1019$ ms, $SD = 208$) than for counterfactual sentences ($M = 1032$ ms, $SD = 212$).

TABLE 2
Experiment 1: Mean key-pressing times (in milliseconds) and standard deviations (in parentheses) as a function of type of sentence, transfer direction, motion direction, and delay

		Delay			
		100		*200*	
Sentence type	*Transfer*	*Away motion*	*Towards motion*	*Away motion*	*Towards motion*
Factual	Away	235 (87)	210 (87)	314 (215)	231 (118)
	Towards	237 (88)	212 (90)	276 (137)	259 (133)
	ACE	2	−2	**−20**	**−28**
Counterfactual	Away	247 (103)	207 (86)	287 (133)	250 (144)
	Towards	242 (102)	219 (87)	299 (173)	239 (128)
	ACE	**−5**	**−12**	12	11

The ACE was the subtraction between pairs of matching–mismatching conditions.

Discussion

Some aspects of these results are remarkable. First, the ACE was obtained in both factual and counterfactual sentences, demonstrating that sensory-motor processes are activated also during the comprehension of counterfactual meaning. Second, the ACE consisted of slower motor responses in the matching (interference) than in the mismatching conditions. This interfering ACE differs from other ACEs reported in the literature that involve matching advantage (Borreggine & Kaschak, 2006; Glenberg & Kaschak, 2002; Kaschak & Borreggine, 2008; Zwaan & Taylor, 2006), although it is coincidental with other studies that obtained similar mismatching advantage when the action word and the motor response temporally overlap (Boulenger et al. 2006; Buccino et al. 2005; de Vega et al., 2011). Differences in the sentence-action delay between this and other studies could be responsible of finding either facilitation or interference in the matching conditions. Thus, whereas in the typical ACE studies the motor responses were tested after understanding the whole transfer sentence in this study the motor response was placed at several intervals following the transfer verb and before finishing the sentence. In this way, the motor action could be placed at the moment in which most of the transfer information (agent, object, and direction of transfer) was integrated in the Spanish sentences. Third, the ACE was short-lived, and its time course differed in the two types of sentences. In counterfactuals, the ACE was established very early on (at about 100 ms), and dissipated rapidly (in 200 ms). By contrast, in factual sentences, the ACE emerged 200 ms after the verb onset. This clearly indicates that the counterfactual dual meaning modulates the activation of embodied representations, speeding up motor resonance, as will be explained in the General Discussion.

Concerning the latency of responses to the probe, the faster responses in the factual as compared to the counterfactual sentences could be related to the information suppression occurring for counterfactuals at the time of the probe test (de Vega et al., 2007), or simply be due to the fact that counterfactuals consume more cognitive resources than factuals because their complex grammar or their dual meaning. In any case, this is not an especially relevant result for the current hypothesis, because no ACE was observed on this measure.

This experiment clearly demonstrated that the comprehension of action-related sentences in either a factual or a counterfactual format interferes with the performance of a matching motor response. The use of a motion cue in this experiment was a very efficient procedure to prompt participants' motor responses at preestablished intervals following the transfer verb onset. However, this technique involves a potential confusion, because the apparent motion itself could interact with the semantics of the transfer verbs. Thus, some papers have reported that understanding motion-related sentences is modulated by the watching of a visual animation that either matches or mismatches the sentence meaning (Zwaan, Madden, Yaxley, & Aveyard, 2004). In this experiment, both the motor and the visual compatibility could influence the observed effects. In the next experiment, the visual animation was substituted by the use of a static cue to prompt participants' finger motion.

EXPERIMENT 2

This experiment was identical to the previous one, except that in each trial, the cue prompting the participants' finger motion away from or towards them was a colour change in the critical transfer verb. In addition, only the 100 ms delay was employed in this experiment with the purpose of replicating the ACE obtained for counterfactuals in the previous experiment.

Method

Participants. Seventy-eight students of Psychology (including 53 women) from the University of La Laguna received credits for their voluntary participation in the experiment. All were native speakers of Spanish.

Materials, procedure, and design. The same stimuli as in Experiment 1 were employed. Like in Experiment 1, the keyboard with a resting-, an away-, and a towards-key was employed, except that the colours red and blue, rather than the arrows, were attached to the towards- and away-key. The sequence of events in each trial was identical to the previous one, except that the

transfer verb remained still on the screen for 100 ms, and then changed colour to either red or blue. For half of the participants, the colour red was the prompt to release the resting-key and move their finger away from them, and the colour blue indicated that they should move their finger towards them and press the corresponding key. For the remaining participants, the colour–motion assignment was reversed. At the offset of the auditory sentence, participants were given a visual word probe and asked to decide whether or not it had appeared in the sentence. Finally, in 30% of trials, there was a memory question related to the sentence content.

Given the arbitrary character of the colour–motion assignment, before starting the experimental session participants received 24 training trials in which they were given a string of symbols (@) in the centre of the screen which, after a variable amount of time, turned red or blue as a prompt for the participants to move their finger in the assigned direction and press the corresponding key.

A repeated-measures factorial design was performed: 2 Sentence type (factual/counterfactual) $\times 2$ Transfer direction (away/towards) $\times 2$ Motion direction (away/towards). The same dependent variables as in Experiment 1 were collected: (1) the releasing time of the resting-key, (2) the time to press the corresponding direction key, (3) the latency for the word probe, (4) the direction response errors, and (5) the probe errors.

Results

Nine participants were discarded from the data because of their poor performance in the memory questions (more than 30% errors). The same data trimming procedure as in Experiment 1 was used. Wrong responses either in the motor task (less than 1%), or the probe task (7%) were also discarded from the reaction time analyses. We will report only on those measures that produced significant results: the key-releasing time and the latency for the word probe. Unlike in the Experiment 1, the key-pressing time did not produce significant results.

Key-releasing time

The Transfer $\times$ Motion interaction was significant, $F(1, 68) = 4.586$, $MSE = 988.953$, $p < .05$. In addition, a three-way interaction, Sentence $\times$ Transfer $\times$ Motion, $F(1, 68) = 7.118$, $MSE = 869.698$, $p < .01$, was also significant. The first interaction is interpreted as a general interference effect, because the matching conditions produced a slower response than the mismatching conditions. To interpret the three-way interaction, we ran separate analyses for factual and counterfactual sentences. In factual sentences, the Transfer $\times$ Motion interaction was absent, $F(1, 68) < 1$. However, in counterfactual sentences, a significant Transfer $\times$ Motion interaction was found, showing again interference in matching conditions, $F(1, 68) = 10.897$, $MSE = 978.463$, $p < .002$ (see Table 3). Post hoc planned comparisons showed longer latencies for ''away transfer-away motion'' than for ''towards transfer-away motion'', $t(48) = 2.74$, $p < .042$, replicating the pattern obtained in Experiment 1 for pressing-time. Moreover, unlike in the previous experiment, ''towards transfer-towards motion'' was significantly longer than ''away transfer-towards motion'', $t(48) = 2.73$, $p < .008$.

TABLE 3
Experiment 2: Mean key-releasing times (in milliseconds) and standard deviations (in parentheses) as a function of type of sentence, transfer direction, and motion direction

		Motion	
Sentence type	*Transfer*	*Away*	*Towards*
Factual	Away	347 (107)	350 (100)
	Towards	345 (101)	347 (99)
	ACE	–2	3
Counterfactual	Away	353 (98)	343 (102)
	Towards	343 (96)	358 (100)
	ACE	**–10**	**–15**

The ACE was the subtraction between pairs of matching–mismatching conditions.

Probe reaction times

Again, a main effect of sentence type was found in this measure, as factual sentences were responded to faster than counterfactuals, $F(1, 68) = 12.780$, $MSE = 5347.440$, $p < .001$. In addition, responses to probes were faster following a towards-key ($M = 875$ ms, $SD = 186$) than following an away-key response ($M = 890$ ms, $SD = 199$), $F(1, 68) = 5.545$, $MSE = 5650.100$, $p < .05$.

Discussion

In Experiment 2, a static cue (colour change) substituted the visual motion cue of the previous experiment. In this way visual motion effects were prevented in the experiment, and the observed interaction only could be characterised as action–sentence compatibility effect. Here too, the interaction between meaning and action was one of interference in the matching conditions, replicating the basic effect observed in Experiment 1. Unlike in the previous experiment, the interval between the word onset and the static cue (colour change) was fixed at 100 ms and thus we could not check the temporal course of the ACE for factuals. Nonetheless, if we consider the results of Experiment 1 and Experiment 2 together, we can observe several interesting facts. In Experiment 1, the ACE emerged earlier in counterfactuals (100 ms) than in factuals (200 ms). Consistently, in the present experiment, ACE was only effective in counterfactuals at the 100 ms interval. From this experiment, we cannot establish the temporal course of ACE in factual sentences. However, by analogy with Experiment 1, we could speculate that the factual ACE was delayed beyond 100 ms and perhaps could be observed in a later, untested delay.

Unlike in Experiment 1, in this experiment the most sensitive measure was the key-releasing time rather than the key-pressing time. A possible explanation for this fact could be that encoding colour change as a cue of directional motion might be slower than encoding the animation cue. We checked this hypothesis by contrasting the whole set of data from Experiment 2 with the data from Experiment 1 corresponding to the 100 ms delay condition, confirming that the key-releasing time was almost 100 ms slower in the former than in the latter (mean colour cue = 350 ms; mean animation cue = 252 ms), $F(1, 113) = 31.42$, $MSE = 67475.722$, $p < .0001$. Therefore, the delay in interpreting the colour cue could make visible the ACE at the releasing-key stage of response.

GENERAL DISCUSSION

The present study explored whether the comprehension of counterfactual sentences activates embodied representations. Previous studies have reported action–sentence compatibility effects when people understand sentences describing actions. These studies employed concrete factual sentences describing transfer events (Borreggine & Kaschak, 2006; de Vega et al., 2011; Glenberg & Kaschak, 2002; Kaschak & Borreggini, 2008), hand or foot actions (Buccino et al., 2005), or hand rotating actions (Zwaan & Taylor, 2006). By contrast, this research compared action-related sentences in either counterfactual or factual format. Counterfactuals posit a challenge to the embodied meaning approach, because they refer to hypothetical rather than to real events and, therefore, constructing the costly embodied representations might be superfluous. We could conceive, for instance, that a shallow representation in terms of propositions could be enough to grasp the dual meaning of counterfactuals. Thus, the sentence ''If my brother had been generous he would have lend me the novel'' could be represented as two propositions corresponding to its dual meaning: (1) false [(brother, generous) & (brother, lend, novel, speaker)], and (2) true [(brother, generous) & (brother, lend, novel, speaker)].

However, our results show ACE in counterfactual and factual sentences alike, which proves that they share a similar embodied representation of meaning. The observed ACE consisted of an early interference in the meaning–action matching conditions that could be interpreted as a genuine motor resonance effect. As explained in the introduction, early interference strongly suggests that understanding action-related sentences recruits similar neural resources as performing matching actions (see also Boulenger et al., 2006; Buccino et al., 2005; de Vega et al., 2011).

But, why should counterfactuals trigger embodied representations? One possible reason relies on their dual meaning. Counterfactuals activate not only a realistic representation in which the events did not happen but also an ''as if'' simulation of the events happening, as a mechanism for undoing reality and imagining

the alternative course of events. The latter simulation could be equivalent to the meaning of a factual statement and, therefore, would share the same embodiment characteristics. A similar idea has been recently proposed to explain how negations activate embodied representations of the negated concepts (Kaup, Yaxley, Madden, Zwaan, & Lüdtke, 2007). Kaup et al. (2007) built pairs of negative sentences sharing an object, in such a way that both of the negated situations implied a different shape of the same object. For instance, the sentence ''There was no eagle in the sky'' implies that the eagle has its wings outstretched, whereas the sentence ''There was no eagle in the nest'' implies that the eagle has its wings folded in. Participants received each sentence followed by a picture that, in the experimental trials, depicted the critical object in one of its shapes (e.g., the eagle with the wigs outstretched), and their task was to verify whether the object in the picture was mentioned in the sentence. The readers' responses were faster when the depicted object matched rather than mismatched the shape implicit in the negated situation, indicating that readers activated a visual representation of the negated object.

It is useful to contrast counterfactuals and negations, because both apparently share similar representational characteristics. Thus, counterfactual sentences although frequently have an affirmative format involve implicit negations corresponding to their realistic meaning (not-p & not-q), as well as an ''as if'' simulation of their alternative meaning (p & q). On their side, negations in spite of having an explicit negative operator (e.g., not) could momentarily activate a ''counterfactual'' representation of the negated events as if they had truly happened (Kaup, Lüdtke, & Zwaan, 2006; Kaup & Zwaan, 2003), followed by the representation of the actual events, namely a scenario with the negated concepts absent. In other words, it seems that both counterfactuals and negations share dual meaning. Furthermore, similar mechanisms for dealing with dual meaning have been proposed for counterfactuals and negations. For instance, counterfactual reasoning requires keeping track of what is really true and what is imagined, although momentarily assumed to be true (Byrne, 2005). In the same vein, the alternative ''as if'' meaning in counterfactuals does not contribute to updating the discourse situation model, but is kept apart and eventually suppressed (de Vega et al., 2007; Urrutia et al., 2011), and the negated situation in negations is not integrated into the representation of the described world, but is buffered in an ''auxiliary'' representational system (Kaup et al., 2007; Kaup & Zwaan, 2003). Finally, as discussed earlier, the unrealistic meaning of both counterfactuals and negations could be associated with embodied representations.

In spite of the obvious parallel between counterfactuals and negations there must be also substantial semantic differences between them to justify so different linguistic constructions. Particularly, why to use the complex grammar of counterfactuals (conditional marker, compose subjunctive tense) if you could employ the simpler negation operator? Here we propose some important differences. First, for negation the representation of the negated events does not contribute to its proper meaning, whereas for counterfactuals the double simulation of actual events and their imagined alternatives contribute to their meaning. We could conceive the simulation of the negated events as an automatic by-product of lexical processing, which is rapidly suppressed to give place to the representation of the actual scenario with the negated events absent. However, when you listen to a counterfactual expression you are invited to consider the actual situation but also to consider for a while the alternative ''as if'' situation (Byrne, 2005). This dual meaning is essential to fully understand the counterfactual, and to accomplish its psychological functions in communication and reasoning, such as establishing causal inferences, learning from experience, or expressing the emotion of regret. Second, negations and counterfactuals differ in their truth values. Whereas negative statements unambiguously shift the truth values of the affirmative counterparts—for instance if the affirmation is true the corresponding negation is false and vice versa (e.g., Nieuwland & Kuperberg, 2008), in counterfactuals the conflicting truth values seem to be acceptable given the coexistence of the two alternative meanings (Santamaria et al., 2005; Thompson & Byrne, 2002). In negations the alternative scenario could be presupposed (e.g., an expected event) but its representation is not relevant for understanding the statement. By contrast, the counterfactual format explicitly instructs the addressee to represent not only the real events (the implicitly negated scenario), but also the alternative scenario, because both are necessary to accomplish counterfactual functions, as explained previously.

This study showed that motor resonance occurs in a narrow temporal window, which slightly differs in counterfactual and factual sentences. Thus, Experiment 1, which provides the most accurate temporal measure of ACE, revealed interference at 100 ms and 200 ms after the verb onset for counterfactuals and factuals, respectively. The different timing of motor resonance in counterfactuals and factuals is quite surprising and even counterintuitive. The results for probe latencies clearly indicate that counterfactuals involve more cognitive cost than factuals, either because they have a more complex syntax or because they involve dual meaning. Therefore, it might be reasonable to expect that resonance were delayed rather than speeded up in these sentences. A tentative explanation of the advanced resonance in counterfactuals requires a few assumptions. First, the timing of motor resonance in the brain is not fixed but it can be modulated by linguistic factors such as focus (e.g., Taylor & Zwaan, 2008) and, in this study, the dual meaning of counterfactuals. Second, the counterfactual context is marked very early in the clause preceding the transfer event; this means that the counterfactual status of the sentence was already being processed when the participant listened to the transfer verb. Third, the processing of the ''as if'' meaning (p & q) starts before that of the realistic meaning that, being a double negation (not-p & not-q), requires more elaboration.[1] With these premises, is easy to conclude that readers of a counterfactual context speed up the ''as if'' meaning associated with the advanced motor resonance perhaps as a strategy to free cognitive resources for elaborating the alternative meaning (the implicit double negation). By contrast, when readers come from a factual context they just process a unique meaning (p & q) and do not need to speed up resonance. We may notice, however, that this study did not trace the whole temporal course of motor resonance. Further research will be necessary, using a larger range of word–action delays, before taking definitive conclusions on the timing of embodied meaning both in factuals and counterfactuals.

[1] This claim is confined to affirmative counterfactuals, like the ones employed here. However, in negative counterfactuals, such as ''if my brother hadn't been generous he wouldn't have lent me the novel'', the ''as if'' meaning is ''not-p & not-q'', and the realistic meaning is ''p & q''. It is an open question, in this case, whether the ''as if'' meaning is processed before or after the realistic meaning.

In sum, this research has clearly demonstrated meaning–action interference during the comprehension of counterfactuals, extending and qualifying the motor resonance hypothesis to nonliteral structures that describe possibilities rather than facts. In spite of the abstract meaning of counterfactuals (they refer to imaginary possibilities rather than real events), their meaning seems to be embodied, at least when their content refers to hypothetical transfer events. Further studies will be necessary to deal with the embodied representations of counterfactuals. Thus, a direct comparison between counterfactuals and negations seems relevant given their semantic similarity as well as difference outlined earlier. It might be also interesting to test whether facilitation in matching conditions also occurs with counterfactual materials when the tasks are similar to those employed in the standard ACE paradigm.

Original manuscript received November 2010
Revised manuscript received May 2011
First published online October 2011

REFERENCES

Barsalou, L., Santos, A., Simmons, W. K., & Wilson, C. D. (2008). Language and simulation in conceptual processing. In M. de Vega, A. Glenberg, & A. Graesser (Eds.), *Symbols, and embodiment: Debates on meaning and cognition* (pp. 245–284). New York, NY: Oxford University Press.

Borreggine, K. L., & Kaschak, M. P. (2006). The action–sentence compatibility effect: It's all in the timing. *Cognitive Science*, *30*, 1097–1112.

Boulenger, V., Roy, A. C., Paulignan, Y., Deprez, V., Jeannerod, M., & Nazir, T. A. (2006). Cross-talk between language processes and overt motor behavior in the first 200 msec of processing. *Journal of Cognitive Neuroscience*, *18*, 1607–1615.

Buccino, G., Riggio, G., Melli, F., Binkofski, V., Gallese, G., & Rizzolatti, G. (2005). Listening to action-related sentences modulates the activity of the motor system: A combined TMS and behavioral study. *Cognitive Brain Research*, *24*, 355–363.

Byrne, R. M. J. (2005). *The rational imagination: How people create alternatives to reality*. Cambridge, MA: MIT Press.

De Vega, M., Glenberg, A. M., & Graesser, A. C. (2008). *Symbols and embodiment: Debates on meaning and cognition*. New York, NY: Oxford University Press.

De Vega, M., Moreno, V., & Castillo, D. (2011). The comprehension of action-related language may cause interference rather than facilitation on matching actions. *Manuscript submitted for publication*.

De Vega, M., Urrutia, M., & Riffo, B. (2007). Canceling updating in the comprehension of counterfactuals

embedded in narratives. *Memory and Cognition*, *35*(6), 1410–1421.

Ferguson, H. J., & Sanford, A. J. (2008). Anomalies in real and counterfactual worlds: An eye-movement investigation. *Journal of Memory and Language*, *58*, 609–626.

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin and Review*, *9*, 558–565.

Kahneman, D., & Tversky, A. (1982). The simulation heuristic. In D. Kahneman, P. Slovic, & A. Tversky (Eds.), *Judgment under uncertainty: Heuristics and biases* (pp. 201–208). New York, NY: Cambridge University Press.

Kaschak, M. P., & Borreggine, K. L. (2008). Temporal dynamics of the action-sentence compatibility effect. *Quarterly Journal of Experimental Psychology*, *61*(6), 883–895.

Kaup, B., Lüdtke, J., & Zwaan, R. A. (2006). Processing negated sentences with contradictory predicates: Is a door that is not open mentally closed? *Journal of Pragmatics*, *38*, 1033–1050.

Kaup, B., Yaxley, R. H., Madden, C. J., Zwaan, R. A., & Lüdtke, J. (2007). Experiential simulations of negated text information. *Quarterly Journal of Experimental Psychology*, *60*, 976–990.

Kaup, B., & Zwaan, R. A. (2003). Effects of negation and situational presence on the accessibility of text information. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *29*(3), 439–446.

Nieuwland, M. S., & Kuperberg, G. R. (2008). When the truth isn't too hard to handle: An event-related potential study on the pragmatics of negation. *Psychological Science*, *19*, 1213–1218.

Pulvermüller, F., Hauk, O., Nikulin, V. V., & Ilmoniemi, R. J. (2005). Functional links between motor and language systems. *European Journal of Neuroscience*, *21*, 793–797.

Roese, N. (2005). *If only: How to turn regret into opportunity*. New York, NY: Broadway Books.

Santamaría, C., Espino, O., & Byrne, R. (2005). Counterfactual and semifactual conditionals prime alternative possibilities. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *31*, 1149–1154.

Santana, E., & de Vega, M. (2011). Metaphors are embodied, and so are their literal counterparts. *Frontiers in Cognition*, 2–90. doi:103389/fpsyg.2011.00090

Stewart, A. J., Haigh, M., & Kidd, E. (2009). An investigation into the online processing of counterfactual and indicative conditionals. *Quarterly Journal of Experimental Psychology*, *25*, 1–13.

Taylor, L. J., & Zwaan, R. A. (2008). Motor resonance and linguistic focus. *Quarterly Journal of Experimental Psychology*, *61*, 896–904.

Taylor, L. J., & Zwaan, R. A. (2009). Action in cognition: The case of language. *Language and Cognition*, *1*, 45–48.

Thompson, V., & Byrne, R. (2002). Reasoning counterfactually: Making inferences about things that didn't happen. *Journal of Experimental Psychology: Learning, Memory and Cognition*, *28*, 1154–1170.

Urrutia, M., de Vega, M., & Bastiaansen, M. (2011). Understanding counterfactuals in discourse modulates ERP and oscillatory gamma rhythms in the EEG. *Manuscript submitted for publication*.

Zwaan, R. A., Madden, C. J., Yaxley, R. H., & Aveyard, M. E. (2004). Moving words: Dynamic mental representations in language comprehension. *Cognitive Science*, *28*, 611–619.

Zwaan, R. A., & Taylor, L. J. (2006). Seeing, acting, understanding: Motor resonance in language comprehension. *Journal of Experimental Psychology: General*, *135*, 1–11.