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Comprehending with the body: Action compatibility in sign language?

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Abstract

Previous studies show that reading sentences about actions leads to specific motor activity associated with actually performing those actions. We investigate how sign language input may modulate motor activation, using British Sign Language (BSL) materials, some of which explicitly encode direction of motion, vs. written English, where motion is only implied. We find no evidence of action simulation in BSL comprehension, but replicate effects of action simulation in comprehension of written English. The results suggest that the perception of motor articulation in the language input interferes with mental simulation involving the motor system.

Keywords: embodiment; sign language; motor system; action-compatibility effect

Introduction

There is now a body of evidence for an *embodied* view of language, according to which language comprehension is based in our bodily experience of the world and involves the same systems necessary for bodily experience. The grounding of language in perception and action has been evidenced in a wide range of behavioral and neuroscientific studies (e.g. Barsalou, Barbey, Simmons & Wilson, 2003; Barsalou, 2008; Beauchamp & Martin, 2007; Gallese & Lakoff, 2005; Glenberg & Kaschak, 2002; Glenberg & Gallese, 2012; Zwaan & Kaschak, 2008). For example, Stanfield and Zwaan (2001) have shown that sentence comprehension involves the activation of specific imagery related to the perceptual and action properties of an event. Participants were faster to verify that a pictured object (e.g. nail) appeared in a preceding sentence when the orientation of the object (e.g. horizontal vs. vertical) in the picture matched that implied in the sentence (e.g. *John hammered the nail into the wall*). Neuroscientific studies have likewise pointed to specific involvement of motor areas in understanding language related to action. For example, as found by Tettamanti, Buccino, Saccuman, Gallese et al. (2005) in an fMRI study, reading sentences describing actions using specific body parts (e.g. *I bite the apple*, *I kick the ball*) activates the area in the motor cortex related to physical use of that body part (e.g. mouth for *bite*, foot for *kick*) (see also Hauk, Johnsrude & Pulvermüller, 2004).

The Action-Sentence Compatibility Effect (ACE), first demonstrated by Glenberg and Kaschak (2002), provides further compelling evidence that we involve our sensori-motor system in language comprehension by mentally simulating the actions and events encoded in language. In the Glenberg and Kaschak (2002) study, participants were presented visually with written sentences that implied either motion toward (*Andy delivered the pizza to you*) or away

from (*You delivered the pizza to Andy*) the body. Participants were asked to judge sentence sensibility by responding with a button press that required movement of the arm either toward or away from the body – i.e. in a direction congruent or incongruent with the direction of motion implied by the sentence. Participants were faster to respond to sentences when the implied motion was congruent with the response direction. This was true of sentences implying transfer in both the concrete and abstract domains (e.g. *You communicated the message to Adam*). In a related study, Borreggine and Kaschak (2006) provided evidence for the ACE when the same English sentences were presented to participants auditorily, unfolding in real time. The Action-Sentence Compatibility Effect suggests that sentence comprehension involves a dynamic mental simulation of the event, in this case, a motor simulation of performing the described action.

As the evidence supporting sensori-motor system involvement in language comprehension accumulates, we must also address the question of how this embodiment comes about. How does language come to be grounded in our bodily experience and what are the mechanisms by which language processing engages the sensori-motor system (cf. Perniss, Thompson & Vigliocco, 2010)? Moreover, there is much debate about how embodiment effects may be modulated by context (cf. Willems & Casasanto, 2011), and how effects may be constrained by different properties of language.

In this context, the strong role of action/motor simulation in sentence comprehension demonstrated by the ACE effect raises an interesting question with respect to the modality of language presentation. Neither the written visual nor the spoken audial presentation of sentences involves the physical use of the motor system. This situation is very different, however, in the case of sign languages. In sign languages, the natural languages of deaf people, meaning is encoded through movement of the hands and arms through the space on and in front of the body. The visual medium of sign language moreover affords a high degree of iconicity, or resemblance between linguistic form and meaning. This potential is exploited particularly for encoding sensori-motor information, such that meanings related to action and motion are expressed in highly iconic linguistic forms. Thus, many sign language verbs encoding transfer of the type studied by Glenberg and Kaschak (2002) explicitly realize directionality of motion in the event through a corresponding movement of the hands through space (i.e. toward or away from the body).

To date, embodiment effects have been studied looking at spoken/written language. Extending the investigation of

embodiment to language expressed in the visual modality, where the same motor articulators that perform non-linguistic actions are used to encode actions linguistically, is an important step to understanding the nature of embodiment, and the conditions under which embodiment effects come about. The simulation effects observed in action sentence comprehension may well be modulated or constrained by inherent properties of language, particularly related to language modality and the potential for iconic representation. To address this question, we ask here how the iconic and motor properties of visual language may affect action simulation in sign language sentence comprehension?

One possible outcome is that we find an effect of action simulation in sentence comprehension consistent with what has been shown for English. The perception of motor action in language, where the linguistic (i.e. phonological) expression of action verbs is realized through directional motion, could boost the involvement of motor simulation in sentence comprehension. In this case, participants should be faster to respond in a direction corresponding to the event (and its realization in sign language), compared to when the response direction is incongruent with the event. It is also possible, however, that we observe an effect in the opposite direction, as the interpretation of the signed sentences may involve mentally taking the perspective of the signer producing them, as we discuss below.

An alternative outcome is that motor simulation of the encoded event in comprehension may be reduced or eliminated by the involvement of the motor system in the articulation of the action. Because viewing sign language means viewing physical movement of the same articulators necessary for the action simulation (here, arms and hands), the simulation itself may be blocked or even unnecessary. Thus, a contrasting prediction is that viewing sentences presented in a sign language would not yield an ACE effect.

To test these contrasting predictions, we investigate ACE effects in deaf users of British Sign Language (BSL).

Experiment 1

We sought to replicate the Glenberg and Kaschak (2002) study using close translations of the original English sentences into BSL. All of the experimental sentences in this study implied directional motion, with equal numbers of sentences referring to motion toward the body and motion away from the body. Within these, half referred to concrete transfer events (as in *You delivered the pizza to Andy*) and half to abstract transfer events (as in *You communicated the message to Adam*).

The BSL sentences not only preserved the specific events described by the English sentences but also their 2nd/3rd person reference structure. In BSL, as in other sign languages, person reference is achieved by directing signs at locations in space associated with the entities being talked about. Second person (*you*) is associated with a location directly opposite the signer, the canonical location of an addressee.[1] Third person (*he/she/it*) is associated with a location to the right or left of the signer. The body of the signer, specifically a location at the center of the signer's chest, is associated with first person (*I*). Points to the appropriate locations indicate the arguments, e.g. subject and object, of a verb. In addition, verb signs themselves – so-called *directional* predicates – can indicate arguments by physically moving between the locations associated with the arguments.[2]

This is illustrated in the BSL example sentence shown in Figure 1, which corresponds to English *James awarded the degree to you.* In the example, 3rd person reference to *James* is achieved in stills 2-3 of the figure, consisting of a sign for the letter 'J' (for James), in still 2, followed by a pointing sign to a 3rd person location to the right of the signer's body, in still 3. The predicate in the final still conveys the meaning *he awards to you* by moving from the 3rd person location associated with *James* to the 2nd person location – outward from and opposite the signer's body – associated with the participant/addressee viewing the sentence. Thus, in the BSL version of *James awarded the degree to you*, participants see the predicate move toward them, in the same way as the actual event would involve movement toward them. In the experiment, participants perceived directional verbs like *award-to* moving either toward or away from them, congruent with the direction of the event.

DEGREE   JAMES-he   he-AWARD-TO-you

Figure 1: Glossed example of BSL sentence. (English translation: *James awarded the degree to you.*) The sentence includes a directional verb that moves from 3rd to 2nd person. The perceived motion in viewing the sentence is thus toward the participant's/addressee's body.

Not all predicates in BSL are directional, however, in this way. Translation of the set of verbs that appears in the original Glenberg and Kaschak (2002) study ignores a crucial contrast between *directional* vs. *non-directional* verb types in BSL. In *non-directional* predicates, the form of the verbs is the same regardless of the direction of the event (e.g. in the verb *write*, the hands represent writing at a location in front of the body regardless of who is writing to whom). Only *directional* predicates encode the direction of the event by moving between the locations associated with their arguments. (See the schematizations of verb types and direction used across experiments provided in Figure 2.)

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[1] In actual discourse, 2nd person reference is achieved by pointing to the physical location of the addressee.

[2] This is a highly simplified description (for a more in-depth treatment see Sandler & Lillo-Martin 2006), but is adequate for the present purposes.

A second set of sentences was designed to address this issue. This set encoded semantically similar events from those of Glenberg and Kaschak (2002), but using different verbs, in order to manipulate the number of directional vs. non-directional verbs that appeared in the sentences. This is important because the ACE effect hinges on the simulation of directional motion, and may be influenced here by the congruence of perceived phonological motion with the motion entailed by the event itself.
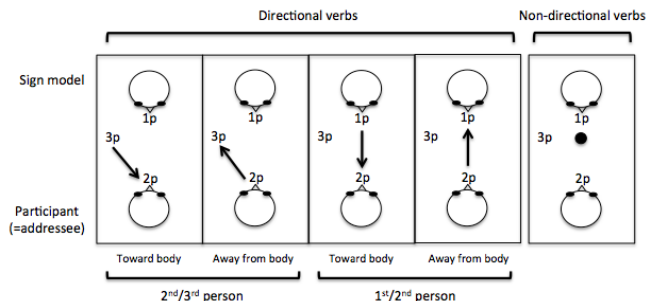

Figure 2. Schematization of verb types, person reference, and direction used across Experiments 1 and 2.

Method

Participants 16 deaf adult signers of BSL were recruited from the greater London area. BSL age of acquisition ranged from 0-13 years (mean 3.13; with 9 native signers who acquired BSL from birth). Participant age ranged between 19-59 years (mean age 34.69). All participants had normal or corrected to normal vision.

Materials For Experiment 1a, the original English sentences (Glenberg & Kaschak, 2002) were translated into BSL by a native deaf BSL signer, and proficient BSL-English bilingual. BSL sentences were videotaped and edited into single sentence clips. All sentences depicted transfer from 2nd to 3rd or from 3rd to 2nd person, corresponding with direction of motion toward or away from the body, respectively (see Figure 1). 20 abstract and 20 concrete events were included, with two sentences depicting each event (one toward the body, one away). 40 nonsense sentences were also filmed, again closely resembling those used by Glenberg and Kaschak (2002). Different test lists were created so that each participant saw only one sentence referring to a given event, with equal numbers of abstract/concrete, toward/away sentences. Sentences were randomly ordered for each participant.

For Experiment 1b, we constructed BSL sentences around events involving 16 directional verbs and 13 non-directional verbs.[3] For each verb we created four sentences, two sensible sentences (one toward the body, one away from the

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[3] We focused on selecting BSL verbs that clearly encoded motion of transfer semantics of the kind needed for the ACE, and did not control for other factors like sentence length. The challenge of finding enough non-directional BSL verbs, in particular, meant that we were not able to achieve an exact balance between the verb types and required use of the same verbs in sensible and nonsense versions of the sentences.

body) and two nonsense sentences (one toward, one away). Each participant saw all four sentences involving a given verb, with materials divided into four blocks so that each verb occurred only once per block and so that conditions were approximately balanced within each block. Order of blocks and order of trials within a block were randomly ordered for each participant. In both experiments, we treated nonsense sentences as fillers, only analyzing the effects of implied directional motion in sentences depicting real events.

Procedure Participants sat directly opposite a computer screen with a response box oriented sagittally in front of them, and were told they would see BSL sentences addressed to them. Participants were prompted to press and hold the middle of three buttons on the response box upon the appearance of a fixation cross in the middle of the screen. Upon pressing the button, a video clip of a BSL sentence began to play, and continued to play as long as the middle button was held down. Participants judged the sensibility of the sentence by moving their finger to press a button either away from or toward their body from the middle button (i.e. to the near or far button on the response box). Participants were told to respond as quickly and accurately as possible. We measured the time it took for participants to release the central button, thus tapping into the motor planning necessary to make their responses (see Borreggine & Kaschak, 2006). Participants came for two sessions, which differed only in the direction of the response for sensible sentences (toward vs. away from the body), with the order of response per session counterbalanced across participants. Experiments 1a and 1b were carried out separately in each session, again with the order counterbalanced across participants.

Results

We analyzed only responses for sensible sentences, excluding errors and using button release latencies as the dependent measure. We analyzed Experiment 1a using 2×2 ANOVA (sentence direction × response congruence). The main effect of sentence direction was not significant; $F(1,15)=3.260$, $p=.091$: a tendency for faster responses for transfer toward the body. Neither the main effect of response congruence and interaction were significant ($F<1$).

For Experiment 1b we conducted 2×2×2 ANOVA also including the factor of verb type (directional vs. non-directional). There was a main effect of sentence direction ($F(1,15)=6.772$, $p=.020$, $\eta^2_{partial}=0.311$); the sentences moving toward the body were faster than those moving away from the body. There was also a main effect of verb type ($F(1,15)=124.933$, $p<.0001$, $\eta^2_{partial}=0.891$); sentences with non-directional verbs were much faster than sentences with directional verbs (2091 vs. 2271 msec respectively), likely due to differences in sentence durations (e.g. directional verbs may take longer on average to execute than non-directional verbs). There was also an interaction between verb type and sentence direction ($F(1,15)=10.442$,

$p=.006$, $\eta^2_{partial}= 0.410$), again presumably related to differences in verb durations. Crucially, the main effect of congruence was not significant ($F<1$), nor were any of the interactions involving congruence (congruence × direction $F(1,15)=1.453$, $p=.247$; congruence × verb type, $F<1$; 3-way interaction $F(1,15)= 3.702$, $p=.074$). See Figure 3.

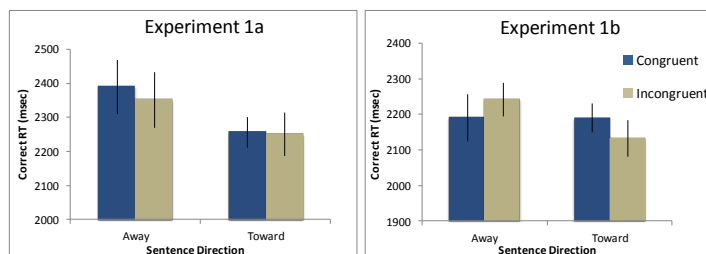We found no ACE effect: there was no main effect of response congruence, nor any interactions involving it.[4]

Figure 3: Results of Experiment 1a (left: BSL replication of Glenberg & Kaschak, 2002) and 1b (right: BSL 2nd/3rd person comparing directional/non-directional verbs). We report correct button release times to sensible sentences as a function of sentence direction (Away (from) or Toward the body) and whether the response direction is congruent or incongruent with the directional event being described. Error bars reflect standard error of the mean (by subjects).

Discussion

In Experiments 1a and 1b we did not find an ACE effect; responses were not faster when the sentence implied an event moving in the same direction as the hand action required to make a sensibility decision. Furthermore, in Experiment 1b there was no difference in response times between when the direction of motion entailed by the action was encoded phonologically (directional verbs) vs. when it was not (non-directional verb). This implies that the lack of action simulation – and thus lack of motor system involvement – may be related to perceiving sign language, which is produced by means of motor movement of the same articulators involved in the actual action event.

However, it may be the case that ACE requires that the direction of the button press converge with the direction of the event. In the 2nd/3rd person transfer used in Experiments 1a and 1b, the BSL directional verbs move diagonally, offset approximately 45° from the center of the producer's body and offset approximately 45° from the participant's direction of response (see Figure 2). If sentence compatibility effects require close directional convergence between the sentence judgment response and the simulated event, this discrepancy could reduce or eliminate ACE effects. Finally, if the lack of an effect in Experiments 1a and 1b is due to the use of sign language in the task, we should be able to observe an ACE effect in the same

participants when they are reading English sentences. Obtaining an ACE effect using English is especially important in the face of the null effects we have reported here, showing that our procedure is sound and our participant number large enough to find evidence for ACE, if it were there.

Experiment 2

Experiment 2a assesses whether the lack of convergence between the direction of motion encoded in the event and the response direction modulates simulation effects. We use BSL sentences that imply transfer between 1st/2nd person, thereby maximizing the overlap in directionality. Sentences that encode transfer between 1st/2nd person (e.g. *I awarded the degree to you*) involve phonological movement between the signer's body (1st person) and a location opposite the signer's body (2nd person). Thus, directional verbs move along the central axis, straight toward or away from the body. This modification of person reference in verbs creates complete directional convergence with the direction of button press response and with the direction of motion entailed by the actual action event. We otherwise used exactly the same materials and procedures as in Experiment 1b, where directional vs. non-directional verbs are compared.

Experiment 2b assesses whether the lack of an effect in Experiment 1 is indeed specific to the use of sign language. The same (BSL-English bilingual) participants who took part in Experiment 2a, also carried out the original experiment by Glenberg and Kaschak (2002) with visual presentation of written English sentences.

Method

Participants A new group of 16 deaf adult BSL-English bilinguals[5] were recruited from the greater London area. BSL age of acquisition ranged from 0-11 years (mean 3.85; with 7 native signers who acquired BSL from birth). English age of acquisition ranged from 0-5 years (mean 2.19). Ages ranged between 18-59 years (mean age 30.75). All participants had normal or corrected to normal vision.

Materials BSL materials for Experiment 2a were the same as for Experiment 1b, but all sentences depicted transfer from 1st to 2nd or from 2nd to 1st person. For the written English experiment, we used the original set of sentences from Glenberg and Kaschak (2002). List creation, task order etc. were the same as in Experiment 1.

Procedure The procedure was the same as in Experiment 1. For English sentences (Experiment 2b), participants saw the written English sentence appear in the middle of the screen.

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[4] The marginal three-way interaction in Experiment 1b arises due to a tendency for congruent trials to be particularly slower than incongruent trials, only in non-directional verbs encoding events moving away from the body. As a result, this provides no evidence compatible with the ACE effect previously reported for English.

[5] Note that the signers recruited for Experiment 1 were also BSL-English bilinguals, a status which holds true of most users of sign language, as they must also be able to communicate in the spoken/written language of the surrounding hearing community.

Results

As in Experiment 1 we analyzed only the responses for sensible sentences, excluding error trials and using button release latencies as our dependent measures. We analyzed Experiment 2a using 2×2×2 ANOVA also including the factor of verb type (sentence direction × response congruence × verb type). None of the main effects reached significance (congruence $F<1$; direction $F(1,15)=2.299$, $p=.150$; verb type $F(1,15)=2.681$, $p=.122$), nor did any of the interactions (congruence × verb type, $F(1,15)=1.246$; $p=.282$; three-way interaction $F(1,15)=3.082$, $p=.100l$; all other $F<1$). As in Experiments 1a and 1b we found no ACE effect in BSL.[6]

We analyzed Experiment 2b using 2×2 ANOVA. Here we found a main effect of congruence ($F(1,15)=10.888$, $p=.005$, $\eta^2_{partial}= 0.421$): an ACE effect in written English. There was a marginal main effect of sentence direction ($F(1,15)=4.353$, $p=.054$) and no interaction ($F<1$). See Figure 4.
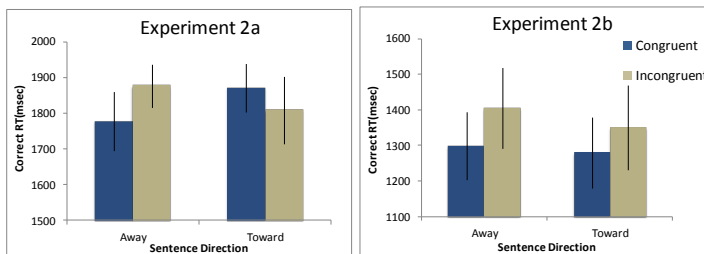

Figure 4: Results of Experiment 2a (left: BSL 1st/2nd person comparing directional/non-directional verbs) and 2b (right: English replication of Glenberg & Kaschak, 2002 with BSL signers). We report correct button release times to sensible sentences as a function of sentence direction (Away (from) or Toward the body) and whether the response direction is congruent or incongruent with the directional event being described. Error bars reflect standard error of the mean (by subjects).

Discussion

As in Experiment 1a and 1b, we find no ACE effect in Experiment 2a: responses to BSL sentences are no faster when the direction of response is congruent with the event depicted by a sentence. But we find reliable ACE effects in English (Experiment 2b), replicating the original Glenberg and Kaschak (2002) study with exactly the same participants as in Experiment 2a. Finding an ACE effect in English vs. no such effect in BSL, in the same population, suggests that action simulation is involved in language comprehension when visually perceiving written language, but not when perceiving signed language.

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[6] Because Experiments 1a and 2a used the same pool of items, varying only in whether the events were 1st/2nd person (Exp. 1a) 2nd/3rd person (Exp. 2a) we also conducted an analysis combining both experiments (N=32) with Experiment as an additional factor. The main effect of congruence was not significant in this analysis ($F<1$) nor any other interactions involving congruence (all $F<1$).

General Discussion

We assessed whether the same effects of action simulation observed during comprehension of English directional sentences can be observed in the comprehension of BSL directional sentences. The ACE effect has been argued to demonstrate that sentence comprehension relies on simulation of the actions encoded in the sentences. Specifically, the ACE effect shows that sentence comprehension is facilitated when the action implied by a sentence is directionally congruent with the action required to judge sentence sensibility.

Operating in the visual-spatial modality, sign language necessarily involves motor movement and utilizes the high potential for action iconicity that the medium affords. These properties of sign language led us to propose two possible outcomes regarding the role of action simulation in sign language comprehension: the action simulation is either boosted or blocked.

We found no evidence for an ACE effect in BSL sentence comprehension across three experiments (1a, 1b, 2a). The results thus suggest that viewing sign language does not engage the motor system in comprehension in the way that has been found for written and spoken presentation of English sentences. These results do not come about because of lack of power: we observed an ACE effect with the same participants when presented with English written sentences. This finding also indicates that it is not knowing a sign language per se that modulates the use of action simulation in sentence comprehension (i.e. in a second language).

The results further suggest that it is not the iconicity between the direction of motion of the action signs and the actual actions that blocks the involvement of action simulation in comprehension, as there was no difference found between directional vs. non-directional verbs.

Why then do we fail to see an ACE effect in BSL? A first possibility is that the lack of involvement of the motor system in comprehension may be related to perceiving the physical engagement of the motor articulators. This engagement would block the system from engaging in sentence simulation. It is also possible that the involvement of our sensori-motor systems in language comprehension depends on the format in which language is presented. The ACE effect has been found previously, and replicated here, only for language presented in a unichannel format – the written or the spoken word. These unichannel formats are not directly evocative of the events encoded in the sentences, they have no explicit visual correspondence to the events being described. They are impoverished in this sense compared to the rich, depictive event representations provided by the visual modality of signed language. Thus, it may be that an "impoverished" unichannel language representation relies on action simulation in comprehension, while a richer, multichannel language presentation – particularly involving depictive, iconic representation – does not. The action may not need to be "filled in" or simulated in the context of a rich, depictive representation of the event.

We cannot rule out, however, that the iconic properties of sign language action predicates play a role in affecting the involvement of the motor system. Even the non-directional verbs, which do not overtly encode the direction of motion of the action, were often iconic of the action in some way (e.g. BSL *pour* which resembles pouring a liquid, but does not vary in its direction depending on who is doing the pouring). Such iconic properties may engage the same effectors in simulation, perhaps with other aspects of the event such as hand configuration and orientation being more salient than generic aspects of directional motion. Our results also do not rule out the possibility that the perception of motor movement at all, and particularly non-iconic movement, may block the involvement of the motor system in comprehension.

Finally, there are a number of further modality-related differences between English and BSL that might have played a role in our study. First, the temporal unfolding of the event is different. Secondly, word order differences may play a role. While the English sentences follow a rigid Subject-Verb-Object order, the BSL sentences typically had the verb in final position (a word order common to many sign languages). Future research on ACE effects in spoken languages with verb-final word order, e.g. Japanese or Turkish, would be illuminating in this regard.

Another issue that bears further investigation relates to perspective-taking in sign language comprehension. Specifically, though participants were informed that they would see BSL sentences addressed to them, sentence comprehension may have involved mentally taking the signer's perspective. If participants mapped their own body onto that of the sign model producing the sentences, mentally imitating the sign model's motor production, this would create a conflict between the congruence between sentence direction and response direction. However, if this were the case, it is likely that we would have seen an ACE effect in the opposite direction. As no effect whatsoever was observed in the BSL versions of the experiments, we do not assume this to have played a role.

Thus, our research suggests that the involvement of action simulation in language comprehension is dependent on the format and modality of language presentation. This is important to our understanding of the conditions under which and the degree to which language comprehension involves simulation. The idea that the use of action simulation may be contextually dependent is in line with previous observations that contextual variables (e.g. abstract vs. concrete contexts) modulate effects of embodiment in terms of differential activation of sensori-motor representation in language processing (Mahon & Carramazza, 2007; Willems & Casasanto, 2011 for a review). Context dependency of the degree to which embodiment (i.e. the involvement of sensori-motor systems) is evident in language comprehension demonstrates a fundamental flexibility, rather than rigidity, of the architecture of language processing.

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