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The Action–Sentence Compatibility Effect: It's All in the Timing

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Abstract

When participants are asked to make sensibility judgments on sentences that describe action toward the body (i.e., "Mark dealt the cards to you") or away from the body (i.e., "You dealt the cards to Mark"), they are faster to respond when the response requires an arm movement in the same direction as the action described by the sentence. This congruence effect is known as the Action–Sentence Compatibility Effect (ACE). This study reports 4 experiments that extend our understanding of the ACE by exploring how the time at which one prepares the motor response required for the sensibility judgment affects the magnitude of the ACE. Results show that the ACE arises only when participants have the opportunity to plan their motor response while they are processing the sentence.

Keywords: Action–sentence compatibility effect; Motor planning; Language comprehension

1. Introduction

Several recent studies suggest that sentences are understood through sensorimotor simulations of the objects, actions, and events being described (e.g., Glenberg & Kaschak, 2002; Kaschak & Glenberg, 2000; Kaschak et al., 2005; Kaschak, Zwaan, Aveyard, & Yaxley, 2006; Richardson, Spivey, Barsalou, & McRae, 2003; Stanfield & Zwaan, 2001). These simulations involve the reactivation of patterns of brain activation that are present when the comprehender actually experiences objects, actions, and events of the sort described in the language (Barsalou, 1999). For example, understanding the sentence, "You gave Meghan the toy," would involve the activation of both perceptual information to simulate the objects being described (e.g., Kaschak et al., 2005; Zwaan, Stanfield, & Yaxley, 2002) and motoric information to simulate the "giving" action of the sentence (e.g., Glenberg & Kaschak, 2002).

The claim that language comprehension involves the activation of sensorimotor information has received support from studies using both behavioral and neuroimaging methodologies. Be-

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havioral studies have shown that perceptual information related to the shape, orientation, and direction of motion of objects is active during sentence comprehension (Kaschak et al., 2005; Kaschak et al., 2006; Stanfield & Zwaan, 2001; Zwaan, Madden, Yaxley, & Aveyard, 2004; Zwaan et al., 2002), as is motor information (Glenberg & Kaschak, 2002). Neuroimaging studies have shown that the processing of words involves the activation of the same neural regions that would be involved in actually perceiving or acting with the referent of the words (Gernsbacher & Kaschak, 2003; Isenberg et al., 1999; Kan, Barsalou, Solomon, Minor, & Thompson-Schill, 2003; Martin & Chao, 2001). For example, processing the names of tools produces activation in brain regions associated with motor planning, and processing words related to visual perception (e.g., color terms) produces activation in brain regions associated with visual processing (for a review, see Pulvermuller, 1999).

Although we believe that producing demonstrations of perceptual and motoric effects during language processing is important to the development of a sensorimotor theory of language comprehension, we believe that it is equally important to find the limits of these demonstrations. The work presented here takes a first step toward this goal by examining limitations on the Action–Sentence Compatibility Effect (ACE) first reported by Glenberg and Kaschak (2002). In the original studies, participants were asked to make sensibility judgments on sentences that described action toward the body ("Mark dealt the cards to you") or away from the body ("You dealt the cards to Mark"). Indicating that the sentence made sense (a "yes" response) required moving one's arm toward the body on one half of the trials and required moving one's arm away from the body on the other half of the trials. The canonical ACE effect is that participants are faster to respond when the direction of motion in the sentence matches the direction of motion required to make the response.

A key feature of Glenberg and Kaschak's (2002) experiment was that participants knew what motor action was required to make a *yes* response throughout the experiment. For example, in some cases participants were told that a *yes* response would require the "toward" motion during the first half of the experiment and an "away" motion during the second half of the experiment. Therefore, participants could begin programming the motor response required to indicate that the sentence was sensible once it became apparent that the sentence was, in fact, sensible. Given the nature of the filler sentences (and the overall ease of the judgment) in Glenberg and Kaschak's experiments, it is likely that participants knew the sentences were sensible at some point before the end of the sentence, meaning that they were likely preparing the *yes* motor response while still processing the sentence.

The question addressed in the experiments presented here is whether the presence of the ACE relies on being able to prepare the motor response required for the sensibility judgment while the sentence is being processed. Our procedure and materials were identical to those used by Glenberg and Kaschak (2002), with the following changes. First, whereas Glenberg and Kaschak used a *yes–no* judgment task, we employed a *go–no-go* methodology wherein participants only made a response when the sentence was sensible. The go–no-go method was selected because it allowed us to change the direction of motion used for the *yes* response from trial to trial, giving us the ability to control the point at which participants knew what response was needed on that trial. Second, whereas Glenberg and Kaschak presented their sentences visually, the design of these experiments necessitated that we present sentences auditorily. Third, we manipulated the point at which the participants became aware of the response that was required to indicate that a sentence made sense. Participants were given a visual cue as to which action (toward or away) would be needed for a yes response at the beginning of the auditory sentence presentation (Experiment 1, replicating the basic temporal parameters of Glenberg & Kaschak, 2002); 50 msec after the end of the sentence (Experiment 2); 500 msec after the sentence (Experiment 3); or 1,000 msec after the end of the sentence (Experiment 4).

Of interest in these experiments is whether the ACE will appear only in conditions where the nature of the motor response is known while the sentence is being processed, or if it will also be found in cases where the motor response is not indicated until some point after the sentence has been presented. The possibility that the ACE will appear only when the nature of the motor response is known while the sentence is being processed would be consistent with recent theoretical accounts of perception and action, such as the Theory of Event Coding (TEC; Hommel, Musseler, Aschersleben, & Prinz, 2001).[1] The TEC proposes that a common, feature-based representational medium underlies the perception of distal objects and the planning of action. These features code various aspects of the percept or action plan, such as directionality or color (e.g., a feature may code that something is to the "right" of the observer or that something is "red"). The TEC further proposes that the features are temporarily integrated into "event codes" during perception and action planning. The integration of the features into an event code serves to bind the relevant features to the thing being perceived or the action being planned. According to the TEC, action planning involves two stages. In the first stage, all of the features relevant to the action plan (e.g., the direction of motion needed) are activated. It is possible for several potential actions to be activating features, and it is possible for a given feature to be activated by more than one potential action. In the second stage, an action is selected for execution. When this happens, the relevant features are integrated into an event code (i.e., they are "bound" to that action) and are, therefore, temporarily unavailable (or less available) for use in the preparation of subsequent actions.

The TEC is supported by numerous reports in the literature on both perception and action planning (for a review, see Hommel et al., 2001). As one example, Stoet and Hommel (1999) asked participants to engage in a task in which there were two stimuli and two responses. When the first stimulus (S1) was presented, participants planned (but did not execute) a first response (R1) with their right or left hand. Later, the second stimulus (S2) was presented, and participants immediately produced a second response (R2) with the left or right hand. Once R2 was executed, participants executed R1. The execution of R2 was slower when R2 shared a feature (e.g., right) with R1 than when R2 did not share a feature with R1. Therefore, binding a feature (right) to the R1 action plan made that feature less available for the implementation of R2. When participants were aware of R1 but were instructed not to prepare the action until after completing R2, Stoet and Hommel found that R2 was executed more quickly when it shared a feature with R1 than when it did not share a feature with R1. R1 activated certain features (e.g., right), but these were not bound into an event code because the R1 action plan was not prepared for execution. The prior activation of a feature needed for R2 primed the execution of R2.

The TEC provides a straightforward account of the ACE. The ACE arises because the motor simulation for the sentence and the motor response for the sensibility judgment share a directional feature (toward or away). We propose (in keeping with the TEC) that there are two stages in the construction of a simulation of the action described in the sentence (akin to the 2 stages of action planning described earlier). In the first stage (which occurs during online sentence processing), the relevant action features (such as toward or away) are activated. These features are not bound into a complete simulation of the action because the comprehender must await the end of the sentence to have enough information to run the full simulation. For example, on reading, “You dealt the cards … ,” there is enough information to know that the action is an away action; but, there is not yet enough information to run the full simulation because it is not yet known who is being dealt the cards. The second stage occurs at the completion of the sentence, once all of the action-relevant information is known. Here, the active features are bound into a full simulation of the action described in the sentence. On this approach, the ACE will arise when participants know the direction of response required for the sensibility judgment while they are processing the sentence. This is because the directional feature activated by the sentence during online processing facilitates the production of a motor response in the same direction as that described in the sentence. Once the sentence has been completed, the active directional feature will be temporarily bound to the simulation of the sentence. The binding will reduce the availability of this feature to the motor planning system. As a result, when the direction of the motor response is not known until after the end of the sentence, the ACE should be eliminated or reversed (for a similar observation, see Richardson, Spivey, & Cheung, 2001).

Although we have discussed at some length the rationale for predicting that the ACE will arise only when the nature of the motor response needed for the sensibility judgment is known while the sentence is being processed, it is possible that the ACE will be present in some or all of the delay conditions. Such a finding would suggest that, contrary to the predictions of theories such as the TEC, the motor activation associated with comprehending a sentence can remain active for some time after the sentence has been understood. This would suggest that the ACE is not based solely in the motor planning system, as motor effects tend to be relatively short lived (for a discussion, see Hommel et al., 2001). Instead, the ACE may be driven, in part, by a post-comprehension translation of the action components of the sentence into a feature code that interacts with a set of features that code the response needed for the sensibility judgment.

2. Experiments 1 through 4

2.1. General method

2.1.1. Participants

A separate group of 48 introductory psychology students participated in each experiment ($N = 192$). The participants received course credit in exchange for their participation. Across all four experiments, the data from a total of 6 participants were replaced due to extremely low accuracy on the experimental task. All other participants had accuracy in excess of 96%. All participants were native speakers of American English.

2.1.2. Materials

The critical sentences for these experiments were the 40 transfer sentences used in Glenberg and Kaschak’s (2002) study. Each sentence had a toward version (“Mark dealt the cards to you”) and an away version (“You dealt the cards to Mark”). In addition, 20 of the transfer sentences described literal, concrete transfer (as in the "Mark" sentences), and 20 of the sentences described abstract transfer ("Andy pitched you the idea"). An additional 40 filler sentences were selected from Glenberg and Kaschak's materials. These fillers served as the nonsensical items in the experiment ("Frank boiled you the sky"). Eighteen additional sentences (9 sensible) were generated to serve as practice items at the beginning of the experiment. All sentences were recorded by a female speaker of American English using the freeware, open-source software program Audacity1.23 (Creative Commons attribution licensure) and played using Null soft Winamp 5.08. Critical sentences are listed in the Appendix.

To ensure that sentences appeared equally often in all four critical conditions of the experiment (away sentences, away response; away sentence, toward response; toward sentence, away response; toward sentence, toward response), we created four counterbalanced lists on which a different set of 10 sentences were assigned to appear in each of the four critical conditions. Sentences were randomly assigned to conditions within the constraints that only 10 sentences could appear in one condition on each list, and a sentence could only appear in a condition once across the four counterbalance lists. On each list, there were an equal number of concrete and abstract transfer sentences in each condition.

2.1.3. Procedure

Participants were randomly assigned to counterbalance lists, with the constraint that an equal number of participants appeared on each of the four lists across the entire experiment. Participants were told they were going to hear a series of sentences, and that they were to decide if the sentence made sense or not. Participants sat with the computer keyboard situated on their lap at a 90° angle from its normal orientation, such that the letter "Q" was situated away from their body, and the letter "P" was situated near their body. To initiate the playing of a sentence, participants pressed and held down the "Y" key on the keyboard. They were told to hold this key down until they made their response. At some point during each trial, the letter P or the letter Q appeared in the center of the computer screen. Participants were told that if they thought the sentence was sensible, they should make a *yes* response by pressing the letter shown on the screen. A P response would be a response toward the body, and a Q response would be a response away from the body. The Y, P, and Q buttons had plastic blocks placed on top of them to facilitate responding. The P or Q appeared on the screen immediately after the onset of the sentence in Experiment 1; 50 msec after the offset of the sentence in Experiment 2; 500 msec after the offset of the sentence in Experiment 3; and 1,000 msec after the offset of the sentence in Experiment 4. If the participant did not think that the sentence made sense, they were told not to make any response. In such cases, the trial timed out after 5 sec. To reduce practice effects, participants first responded to 18 practice items (9 sensible). These practice items smoothly transitioned into the critical part of the experiment so that participants would not be aware of the change.

2.1.4. Design and analysis

The dependent variable was the time required to press the P or Q button on each trial. In Experiment 1, where the response cue was presented right after the onset of the sentence, the response time (RT) was measured from the onset of the sentence to the actual response. To adjust for length differences across sentences, we subsequently subtracted the sentence length (in milliseconds) from the RT (such that a response of 0 msec would be a response made at the very end of the sentence). In Experiments 2, 3, and 4, RT was measured from the onset of the response cue.

The data were analyzed as follows: First, all incorrect responses were removed from the dataset. Next, we screened for outliers by removing all RTs that were more than 2 *SD*s from the each participant's RT in each of the four critical conditions (away sentence, away response, etc.). The remaining data from each experiment were analyzed using a 2 (transfer type: abstract vs. concrete) × 2 (Sentence Direction: away vs. Toward) × 2 (Response Direction: away vs. Toward) × 4 (Counterbalance List: List 1, List 2, List 3, List 4) mixed-factor analysis of variance (ANOVA) with *Counterbalance List* as a between-subject factor. Effects involving the Counterbalance List factor are of little theoretical interest, so they are not reported below.

2.2. Results

In each experiment, the critical question is whether we observe the ACE. The ACE manifests itself as a significant Sentence Direction × Response Direction interaction, such that responses are faster when the direction of the sentence matches the direction of the response than when the direction of the sentence mismatches the direction of the response. For the sake of brevity, we do not extensively report the results of nonsignificant tests.

2.2.1. Experiment 1

Experiment 1 was designed to replicate and modestly extend Glenberg and Kaschak's (2002) original ACE study. The response cue was presented at the onset of the sentence, such that participants knew what response needed to be made while processing the sentence (as in the original study). The design provides a small extension of the original phenomenon, showing that the ACE can be found with auditory sentence presentation and in a go–no-go task. The results are presented in Fig. 1.[2] The ACE effect (i.e., the Sentence Direction × Response Direction interaction) was significant: $F(1, 44) = 7.87$, $MSE = 227{,}634$, $p = .008$. There were also

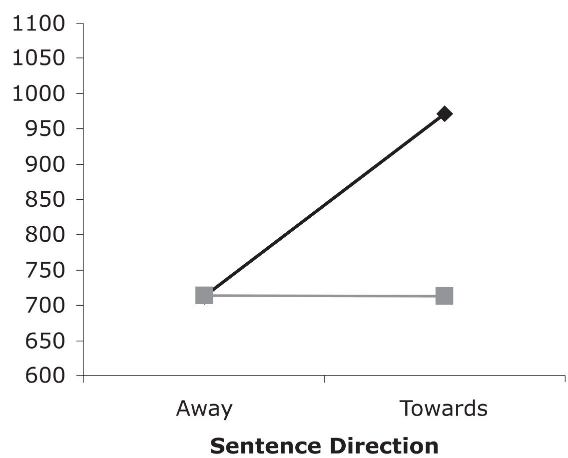

Fig. 1. Mean response times (as a function of Sentence Direction and Response Direction) for Experiment 1.

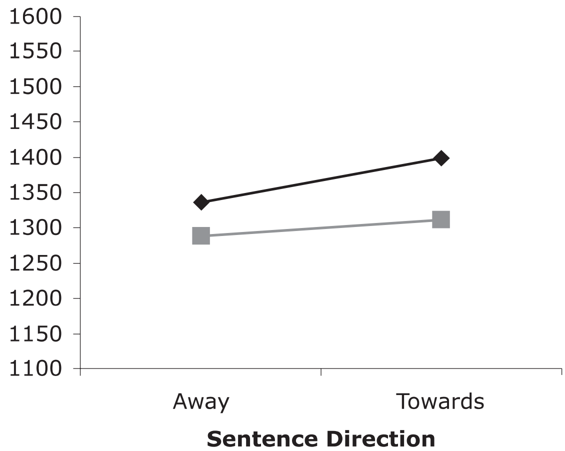

Fig. 2. Mean response times (as a function of Sentence Direction and Response Direction) for Experiment 2.

main effects of Sentence Direction, $F(1, 44) = 6.37$, $MSE = 280{,}541.984$, $p = .015$; and Response Direction, $F(1, 44) = 5.08$, $MSE = 365{,}326$, $p = .029$. There were no significant effects involving the *transfer type* variable (all *F*s < 1.54), showing that the ACE was equally strong for both abstract and concrete transfer situations.

2.2.2. Experiment 2

Experiment 2 was designed to test for the presence of the ACE when the response cue was presented 50 msec after the end of the sentence. The data are presented in Fig. 2. The critical Sentence Direction × Response Direction interaction was not significant ($F < 1$). There were no significant main effects or interactions involving the transfer type, Sentence Direction, or Response Direction variables (all *F*s < 2.10, $p > .15$). Therefore, even a short lag between the processing of the sentence and the presentation of the response cue eliminates the ACE.

2.2.3. Experiment 3

In Experiment 2, delaying the presentation of the response cue until 50 msec after the offset of the sentence eliminated the ACE. Experiment 3 was designed to test the nature of this effect. One possibility is that the ACE would flip in the opposite direction (i.e., responses are faster when the Sentence Direction mismatches the Response Direction) because the directional feature (toward or away) used to simulate the action of the sentence is temporarily less available to program and execute the response needed for the sensibility judgment (e.g., Hommel et al., 2001). This reversal might take longer than 50 msec to arise, however, as some participants may still have been completing their processing of the sentence in that short window of time. Therefore, we extended the delay between the sentence offset and the presentation of the response cue to 500 msec.

The results are presented in Fig. 3. Although participants were faster to respond when the Sentence Direction mismatched the Response Direction, the Sentence Direction × Response Direction interaction was not significant ($F < 1$). The only significant effect involving the transfer type, Sentence Direction, and Response Direction variables was a Transfer Type ×

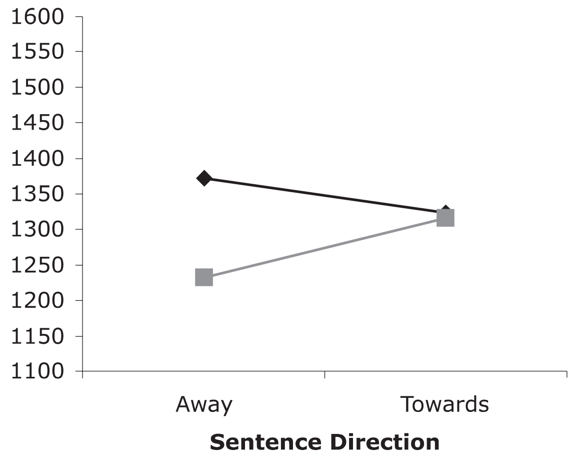

Fig. 3. Mean response times (as a function of Sentence Direction and Response Direction) for Experiment 3.

Response Direction interaction: $F(1, 44) = 4.90$, $MSE = 449{,}313$, $p = .032$. Participants made away responses faster than toward responses for the abstract transfer sentences; the opposite pattern held for the concrete transfer sentences.

2.2.4. *Experiment 4*

Experiment 4 extended the delay between sentence offset and the presentation of the response cue to determine if the nonsignificant reversal of the ACE observed in Experiment 3 would strengthen with a longer delay period.

The results are presented in Fig. 4. As in Experiment 3, participants were faster to respond when the Sentence Direction mismatched the Response Direction, but the Sentence Direction × Response Direction interaction was not significant: $F(1, 44) = 1.53$, $MSE = 795{,}373$, $p = .223$. The only significant effect involving the transfer type, Sentence Direction, and Response Direction variables was a Transfer Type × Sentence Direction interaction: $F(1, 44) = 6.26$,

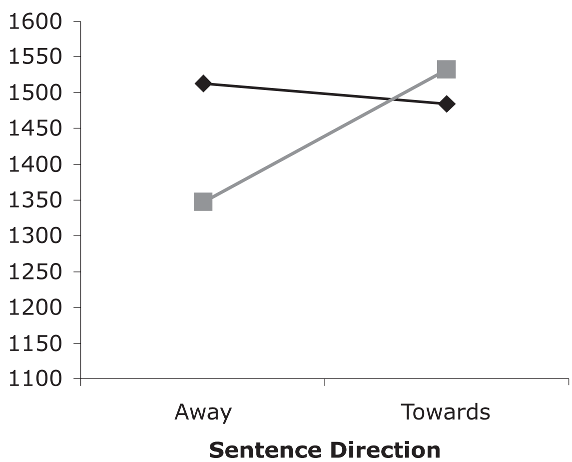

Fig. 4. Mean response times (as a function of Sentence Direction and Response Direction) for Experiment 4.

MSE = 541,539, *p* = .016. For abstract transfer situations, participants were faster to respond to toward sentences than away sentences; the reverse pattern was true for the concrete transfer situations.

2.3. Analysis across experiments

Experiments 1 through 4 demonstrate that the ACE is present when the nature of the motor response required for the sensibility judgment is known while the sentence is being processed, and that the ACE is absent when the nature of the motor response is not known until after the sentence has been presented. To further strengthen this conclusion, we performed statistical analyses using the data from all four experiments. Of particular interest is whether there is an interaction of Delay Condition (simultaneous, 50 msec, 500 msec, 1,000 msec), Sentence Direction, and Response Direction such that the ACE interaction (Sentence Direction × Response Direction) differs across delay conditions.

One concern in conducting this analysis was that the RTs in the simultaneous condition (Experiment 1) were several hundred milliseconds shorter than the RTs in the other delay conditions (Experiments 2–4), largely because participants could respond at any time during the trial in the simultaneous condition, but needed to wait for a response cue in the other conditions. Such differences in scale can make the detection and interpretation of interactions difficult (e.g., Loftus, 1978). To put the data from all four experiments on the same scale, we converted the RTs from each experiment into *z* scores. The resulting *z* scores were submitted to a 4 (Delay Condition) × 2 (transfer type) × 2 (Sentence Direction) × 2 (Response Direction) × 4 (Counterbalance List) mixed-factor ANOVA with Delay Condition and Counterbalance List as between-subject factors. To increase the power of these analyses, we excluded from the statistical design any high-order interactions (4- or 5-way interactions) that did not account for an appreciable amount of variance (as evidenced by *F* values < 1).

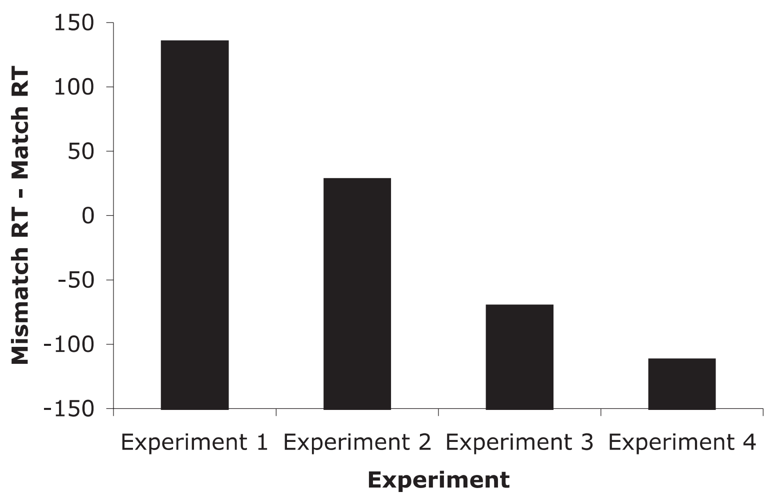

Fig. 5. Magnitude of the Action–Sentence Compatability Effect (mismatch response times – match response times) across experiments.

Fig. 5 depicts the magnitude of the ACE (calculated as "mismatching RTs – matching RTs" such that the standard ACE results in a positive number, and a reversed ACE results in a negative number) across experiments. The interaction of Delay Condition, Sentence Direction, and Response Direction was significant: $F(3, 185) = 2.66$, $MSE = 0.2866$, $p = .049$. We conducted follow-up tests comparing the Sentence Direction × Response Direction interaction of the simultaneous condition (Experiment 1) to interaction in each of the delay conditions. The ACE effect in the simultaneous condition did not significantly differ from the ACE effect in the 50 msec Delay Condition, $F(1, 88) = 2.00$, $MSE = 0.211$, $p = .16$; but it did significantly differ from the ACE effect in the 500 msec Delay Condition, $F(1, 88) = 5.29$, $MSE = 0.294$, $p = .024$; and the 1,000 msec Delay Condition, $F(1, 88) = 7.04$, $MSE = 0.252$, $p = .009$. Therefore, although the reversals of the ACE effect seen in Experiments 3 and 4 were not significant in and of themselves, these reversals do represent a significant change from the ACE effect seen in the Experiment 1.

3. General discussion

Experiment 1 replicated the ACE using a different experimental paradigm than that used by Glenberg and Kaschak (2002). This result joins with Glenberg and Kaschak's data to demonstrate that the ACE arises under conditions in which the participant is able to prepare the motor response required for the sensibility judgment while also processing the sentence. Experiments 2, 3, and 4 presented the response cue after the offset of the sentence. The ACE was eliminated in all three cases.

These findings are consistent with the TEC theory of perception and action (Hommel et al., 2001). The TEC suggests that priming between motor responses will occur under conditions in which similar features (such as a toward direction) are required for responses that are simultaneously active. Therefore, if the toward feature is activated in preparation for execution of the sensibility judgment, and the action described in the sentence also activates the toward feature, priming will occur. On the other hand, when one of the responses is completed (such as running a full simulation of the motor program needed to comprehend the sentence), the common feature (toward direction) will be bound to that response, making it temporarily unavailable (or less available) to other responses (such as the toward response needed for the sensibility judgment). Under these circumstances, priming between motor responses will be eliminated and may be reversed (Hommel et al., 2001).

Although we believe that the presence (or absence) of the ACE in our experiments is consistent with the mechanisms proposed by the TEC, it is worthwhile to note that the data the TEC is intended to explain come from tasks quite different from sentence comprehension. A typical task might involve participants producing manual responses (right or left hand) to a simple cue such as an arrow pointing to the right or left. The cue and response are well circumscribed in these experiments, and both events take place in a short window of time. This contrasts with the process of comprehending a sentence, where many sources of linguistic and nonlinguistic information are used to build an interpretation of the sentence across time (e.g., MacDonald, Pearlmutter, & Seidenberg, 1994). We do not presently see any particular difficulty in applying the principles of the TEC, particularly the distinction between activating and integrating features, to tasks such as ours. Nonetheless, making the connection between the ACE (and other motor effects in sentence processing) and the mechanisms of the TEC more explicit will require a detailed understanding of when the linguistic input activates motor information, how long the motor information remains active, and what the exact nature of this motor information is.

There are two key components to our account of the ACE. First, in keeping with the distinction between activating and integrating features discussed in the TEC, we claim that action-relevant features (such as direction of motion) are activated during online sentence processing, but are not bound to the simulation of the sentence until the sentence has been fully processed. Second, we claim that the ACE was found in our Experiment 1 and in Glenberg and Kaschak's (2002) experiments because participants decided to execute the action required for the sensibility judgment before they had reached the end of the sentence (i.e., before the full simulation was run).

The data reported here (and in Glenberg & Kaschak, 2002) provide support for the claim that participants decided to execute the sensibility judgment before reaching the end of the sentence to be judged. If we grant that the RTs in Experiments 2 through 4 reflect the time it takes to physically make the sensibility judgment response once the Response Direction is known (as it is likely that participants had decided whether the sentence was sensible prior to seeing the response cue), it is noteworthy that the RTs in Experiment 1 are several hundred milliseconds faster than the RTs in the other three experiments. This suggests that participants have begun to initiate their response before the conclusion of the sentence. It is also noteworthy that the ACE effect reported by Glenberg and Kaschak appeared in the reading time for the sentences (i.e., the time from the onset of the sentence until the participant released the button they were pressing to produce the sensibility judgment response) rather than in the time required for the physical response of the sensibility judgment. This could only have occurred if the participants started planning the response for the sensibility judgment before they finished processing the sentence.

Our claim that action-relevant features are activated during sentence processing, and only later bound to the simulation of the sentence, is consistent with Townsend and Bever's (2001) Late Assignment of Syntax Theory (LAST) of sentence processing. LAST proposes that initial stages of sentence processing are aimed at getting a "quick-and-dirty" general interpretation for the sentence. Once this is complete, a more detailed interpretation is constructed. Similarly, we are proposing that the motor information activated during online sentence processing is a "general pass" at the action being described. We consider this action a general pass at the action because the action cannot be fully specified until all the information from the sentence is presented. For example, on reading, "Meghan gave the ball … ," the comprehender may have a general idea about the parameters of the action being described. Nonetheless, full specification of the action must be delayed until later, when all of the parameters of the action are known. For example, a "giving" action cannot be fully specified until the nature of the giver, givee, and the thing being given are known (for a similar argument, see Zwaan & Taylor, 2006). Once all of the relevant information is known, the action being described can be fully specified, and a detailed simulation of the event described in the sentence can be run.

The data reported here have helped elucidate the nature of the ACE. Our results show that the ACE arises only when comprehenders have the ability to prepare and execute the motor response needed for the sensibility judgment while processing the sentence. This conclusion places important constraints on the developing sensorimotor approach to sentence processing.

Notes

1. Certain components of the Theory of Event Coding (TEC; such as proposals for an abstract, amodal level of action coding) are at odds with the sensorimotor view of sentence processing we discuss in this article. For these purposes, our interest is in the predictions that the TEC makes about what information is available at different points in the motor planning and motor execution process. It remains to be seen whether the representations are better represented in modal or amodal terms.
2. Because there are no effects involving the *transfer type* variable that are of theoretical interest, all figures present data collapsed across this variable.

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Appendix

The critical sentences for Experiments 1 through 4 are listed below. The "toward" version of each sentence is listed on top.

Alex forked over the cash to you.
You forked over the cash to Alex.

Andy delivered the pizza to you.
You delivered the pizza to Andy.

Helen awarded a medal to you.
You awarded a medal to Helen.

Jack kicked the football to you.
You kicked the football to Jack.

Vincent donated money to you.
You donated money to Vincent.

Amber drove the car to you.
You drove the car to Amber.

Mark dealt the cards to you.
You dealt the cards to Mark.

Kelly dispensed the rations to you.
You dispensed the rations to Kelly.

Jeff entrusted the key to you.
You entrusted the key to Jeff.

Katie handed the puppy to you.
You handed the puppy to Katie.

Christine bought you ice cream.
You bought Christine ice cream.

Diane threw you the pen.
You threw Diane the pen.

Joe kicked you the soccer ball.
You kicked Joe the soccer ball.

Sally slid you the cafeteria tray.
You slid Sally the cafeteria tray.

Courtney handed you the notebook.
You handed Courtney the notebook.

Shawn shot you the rubber band.
You shot Shawn the rubber band.

Mike rolled you the marble.
You rolled Mike the marble.

Your dad poured you some water.
You poured your dad some water.

Heather slipped you a note.
You slipped Heather a note.

Paul hit you the baseball.
You hit Paul the baseball.

Adam conveyed the message to you.
You conveyed the message to Adam.

You sold the land to Mike.
Mike sold the land to you.

Art bestowed the honor upon you.
You bestowed the honor upon Art.

Sara transmitted the orders to you.
You transmitted the orders to Sara.

The policeman radioed the message to you.
You radioed the message to the policeman.

Tiana devoted her time to you.
You devoted your time to Tiana.

Anna transferred responsibility to you.
You transferred responsibility to Anna.

Dan confessed his secret to you.
You confessed your secret to Dan.

John dedicated the song to you.
You dedicated the song to John.

Ian received the complaint from you.
You received the complaint from Ian.

Jenni sang you a song.
You sang Jenni a song.

Jesse gave you another chance.
You gave Jesse another chance.

Steve lavished you with praise.
You lavished Steve with praise.

Amanda paid you tribute.
You paid Amanda tribute.

Chris offered you some writing tips.
You offered Chris some writing tips.

Your sister blew you a kiss.
You blew your sister a kiss.

He taught you a lesson.
You taught him a lesson.

Liz told you the story.
You told Liz the story.

Your family sent you regards.
You sent your family regards.

Andy pitched you the idea.
You pitched Andy the idea.