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Where Action Meets Linguistic Meaning: Embodied Experience and Sentence Comprehension

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WHERE ACTION MEETS LINGUISTIC MEANING: EMBODIED EXPERIENCE AND SENTENCE COMPREHENSION

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ABSTRACT

How is knowledge accessed when recognizing an object, understanding a concept, or comprehending a sentence? We look at the relationship between linguistic meaning and neural systems of perception and action. More specifically, we look at how these systems of perception and action are closely tied to sensorimotor experiences or bodily interactions with the world, and that these sensorimotor experiences are reactivated during the comprehension of sentences. We further investigated the specificity of the phenomena referred to as Action Sentence Compatibility Effect (ACE), which suggests that language processing affects planning and execution actions to investigate questions regarding the specificity of this motor compatibility effect. In three experiments we examine how the urgency of the action described in the sentences modulates the temporal specificity of both the perceptual and motor information necessary to plan and execute actions, the role perspective taking has in the comprehender's interpretation of the sentence, and establishing more precise time measures during the comprehender's preparation and execution of the motor response.

INTRODUCTION

How is knowledge accessed when recognizing an object, understanding a concept, or comprehending a sentence? Traditionally, cognitive scientists sought to address these questions by analyzing cognitive processes as symbol systems that use abstract, amodal representations that are manipulated by arbitrary rules (e.g., Burgess & Lund, 1997; Chomsky, 1980; Fodor, 2000; Kintsch, 1988; Pinker, 1994). Characterizing linguistic meaning in terms of abstract, amodal representations has been common approach, but a growing field within cognitive science, known as embodied cognition, suggests that cognitive processes are rooted in our sensorimotor experiences or bodily interactions with the world and that these sensorimotor experiences are intimately tied to systems of perception and action (Barsalou, 1999; Glenberg, 1997).

Embodied cognition suggests that we understand the sentence "Joe handed you the pen" by reactivating the relevant perceptual representations and motor information to construct a sensorimotor simulation or mental simulation of the object (e.g. pen), action (e.g. transfer of the pen to you), and the agent (e.g. Joe) described in the sentence (Barsalou, 1999; Glenberg, 1997). Essentially, the comprehender forms a mental representation of the described state of affairs (Johnson-Laird, 1983; Van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998) and continually updates the mental representation of the objects, events, and actions being described in the sentence. The basic premise is that the content of the sentence acts as a set of cues that direct the comprehender to construct an appropriate sensorimotor simulation of a given situation. Thus, the comprehender is immersed and comprehension becomes vicarious experience of the described sentence (Zwaan, 2004).

In this paper we review the relevant behavioral and neuroscience findings that support the idea that language is understood through sensorimotor simulations of objects, events and actions being described (Kaschak & Glenberg, 2000; Zwaan, 2004). First, we present behavioral findings that demonstrate perceptual information related to shape, orientation, and direction of motion that is active during sentence comprehension and affects how that information modulates motor responses. Second we review a phenomena referred to as the action-sentence compatibility effect (ACE) which suggests language processing affects the planning and execution of actions, and is sensitive to a specific temporal window (Glenberg & Kaschak, 2002; Borreggine & Kaschak, 2006; Kaschak & Borreggine, in press; Zwaan & Taylor, 2006). Third, we present converging evidence from neuroscience that describes some of the neural substrates involved in cognition. Finally, we revisit the action-sentence compatibility effect and use this paradigm as a vehicle for addressing a broader range of questions in three proposed experiments that examine: sentences using verbs of motion describing pushing and pulling actions, the role perspective taking plays in constructing the sensorimotor simulation, and how adverbs expressing time modulate both the perceptual and motor information needed to construct the sensorimotor simulation.

The view that language comprehension involves the activation of sensorimotor information has been supported by several behavioral studies that have shown that perceptual information related to the shape, orientation, and direction of motion is active during sentence comprehension as is motor information (e.g., Kaschak, et al., 2005; Kaschak, Zwaan, Aveyard, & Yaxley, 2006; Borghi, Glenberg, Kaschak, 2004; Zwaan, Madden, Yaxley, & Aveyard, 2004; Richardson, Spivey, Barsalou & McRae, 2003; Zwaan, Stanfield & Yaxley, 2002; Connell, 2007; Holt & Beilock, in press, e.g., Glenberg & Kaschak, 2002; Zwaan & Taylor, 2006; Borreggine & Kaschak, 2006; Kaschak & Glenberg, 2000; Kaschak & Borreggine, in press). For example, Stanfield & Zwaan (2001) asked participants to verify that a picture (e.g., of a pencil) depicted an object mentioned in the sentence (e.g., The pencil is in the cup). The study found that pictures matching the implied orientation of the object (e.g., a pencil depicted vertically in this case) were responded to faster than pictures of the object in an orientation that mismatched the orientation implied by the sentence. Thus, understanding the sentence appears to call on experience with real pencils and cups and the orientations that these objects take on during sentence comprehension. Similar interactions between perceptual representations and language processing have been reported by Kaschak et al. (2005; 2006)

Behavioral evidence has also suggested that language processing can affect planning and execution of motor actions. Glenberg and Kaschak (2002) reported a phenomena referred to as the action sentence compatibility effect, which suggests that comprehending a sentence that implies action in one direction (e.g. “Close the drawer”) (e.g. away from the body arm action) interferes with a real action in the opposite direction (e.g. movement of the arm toward the body). Glenberg and Kaschak (2002) presented participants with sensible and non-sensible sentences such as "He closed the drawer" or "Jack boiled the sky," and participants were asked to indicate whether or not the sentence was sensible by pressing one of two directional buttons on a vertically arranged button box. At the beginning of a trial, the participants held their finger on the middle neutral button and then moved either away or toward their body by pressing one of the two directional buttons. Responses toward the participant were facilitated when the sentence described an action requiring the hand to move toward the protagonist (e.g., opening a drawer) and responses away from the participant were facilitated when the sentence described an action away from the protagonist (e.g., closing a drawer). The results suggested that participants were faster to respond when the direction of motion in the sentence matched the direction of motion required to make the response. A key feature of these experiments 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), 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.

In a follow up to Glenberg and Kaschak's (2002) findings Borreggine and Kaschak (2006) demonstrated in 4 experiments that the ACE effect relied on being able to prepare the motor response required for the sensibility judgment while the sentence is being processed. The procedure and materials were identical to those used by Glenberg and Kaschak (2002), with the following modifications. First, while Glenberg and Kaschak (2002) 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, while Glenberg and Kaschak (2002) presented sentences visually, the design of these experiments necessitated that the sentences be presented auditorily. Third, Borreggine and Kaschak (2006) manipulated the point at which the participants became aware of the response that was required to indicate that a sentence made sense. Also, participants were given a visual cue as to which action (towards or away) would be needed for a "go" response at the beginning of the auditory sentence presentation.

In effort to demonstrate that the ACE relied on being able to prepare the motor response while the sentence is still being processed Borreggine and Kaschak (2006) first replicated the basic temporal parameters of Glenberg & Kaschak (2002) in which the auditory sentence and visual cue were presented simultaneously giving the participant time to plan the motor response. Experiments 2, 3, and 4 presented the visual cue at time points after the termination of the auditory file, which prevented the participant from planning the required motor response. The visual cue was presented at 50, 500, and 1000 ms after termination of the auditory file. In all three delay conditions the ACE was eliminated strengthening the evidence that the compatibility effect 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 (Borreggine & Kaschak, 2006).

These findings are consistent with the Theory of Event Coding (TEC) (Hommel, Musseler, Aschersleben, & Prinz, 2001) which posits that a common, feature-based representational medium underlies the perception of distal objects and the planning of action. TEC suggests that priming between motor responses will occur under conditions in which similar features (such as a "towards" direction) are required for responses that are simultaneously activated. Thus, if the "towards" feature is activated in preparation for execution of the sensibility judgment, and the action described in the sentence also activates the "towards" 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 ("towards" direction) will be bound to that response, making it temporarily unavailable (or, less available) to other responses (such as the "towards" response needed for the sensibility judgment). Under these circumstances, priming between motor responses will be eliminated and may be reversed (Hommel et al., 2001). The results support Glenberg and Kaschak's (2002) study and extend the previous study by demonstrating that the ACE arises only when comprehender's have the ability to prepare and execute the motor response needed for the sensibility judgment while processing the sentence.

While, the previous experiments focused on observing what happens when the nature of the motor response was known either at the beginning or after the termination of the auditory sentence file (Borreggine & Kaschak, 2006), Kaschak & Borreggine (in press) explored how the compatibility effect changes when the motor response is planned and executed at different time points within the sentence itself, specifically the visual cue was presented 500, 1500, and 2000 ms after the onset of the auditory sentence file. The ACE appeared in the 500 ms condition, but not in the other two conditions. The presence of the ACE in the 500 ms cue presentation condition reflects the activation of directional features (towards or away) by both the content of the sentence and the motor response. The absence of the ACE in the 1500 ms and 2000 ms cue presentation conditions is a consequence of the relevant directional features being bound to the simulation of the action. From this evidence it is estimated that the running of the simulation (and consequently, the binding of features) occurs between 500 and 1900 ms before the end of the sentence

The behavioral studies complement the evidence that support the claim that concepts make direct use of sensory-motor circuits in the brain with respect to Neuroscience (Gallese and Lakoff, 2005). For example, evidence gathered through Positron Emission Tomography (PET) indicates that the naming of tools, as opposed to the naming of animals, differentially activates the left middle temporal gyrus, which is also activated by action generation tasks. Additionally, the left middle temporal gyrus was also activated when the participant was asked to silently imagine using the tools (Martin, Wiggs, Ungerleider and Haxby, 1996). Demonstrating that the processing of words, particularly the names of tools involves the activation of the same neural regions that would be involved in both perceiving and interacting with the referent (e.g., Isemberg et al., 1999; Kan et al., 1999; Gernsbacher & Kaschak, 2003; Martin & Chao, 2001; Pulvermuller, 1999; Buccino, et al., 2005) offers additional evidence in support of perceptual motor representations.

In a Functional Magnetic Resonance Imaging study (fMRI) Chao and Martin (2000) presented participants with pictures of tools and other objects such as faces and animals. In one experiment the task was to passively observe the pictures, and in the second experiment the participants were asked to silently name the pictures. In both experimental manipulations the tool based pictures showed similar motor activation but the pictures associated with faces and animals produced activation in regions not associated with action representation.

The neuroscience and behavioral studies suggest that we activate perceptual-motor simulations, but the extent to which these simulations are specific is still a matter of debate. The 3 experiments proposed take a step towards pinning down the specificity of ACE phenomena are by examining 1) a different sort of action sentence than the ones that have been previously explored in motor interference paradigms, 2) the role first person vs. third person perspective has in sentence comprehension, 3) the temporal specificity of the preparation and execution of actions by presenting the comprehender with a sentence describing an urgent or non-urgent action.

In order to develop a better understanding of these dimensions, we first sought to understand whether sentences describing pushing and pulling actions activates similar perceptual and motor information as the sentences used by Glenberg & Kaschak (2002), which described towards and away actions. If the sensorimotor simulation constructed during pushing and pulling actions overlaps with that of the previous ACE findings this would suggest that the effects extend across a broader range of goal-directed actions, which supports the theoretical framework of TEC suggesting that the required motor response and directionality feature described in the sentence are only required to share "some common features" for priming to occur. Thus, if the towards perceptual feature is activated during preparation of the simulation, and the sentence involves an action of "pulling" TEC would suggest there are enough common features concerning the perceived directionality of the sentence and directionality of motor to yield similar effects to the previously described compatibility effects. The hypothesis for experiment 1 is as follows: if the pushing and pulling sentence simulations share common directionality features with the towards and away motor responses, a sentence describing the "pushing" action should be processed faster when coupled with a required away motor response. This finding would be similar to the match advantage described in earlier ACE manipulations (2002).

The hypothesis for Experiment 1 suggest sentences describing pushing and pulling actions share common perceptual features with the directional features of away and toward key presses, suggesting that a similar priming would be present when the comprehender has time to prepare and execute the motor response. Experiment 2 was designed to examine the mechanisms of motor planning and execution by separately inspecting the time required to prepare or comprehend the sentence and time needed to execute the motor response or key press. In terms of TEC Experiment 2 helps establish a more precise timeline of how long motor features are bound to the simulation during sentence comprehension by collecting reactions times during the preparation of an action and a second time that is collected during execution or key press. The reaction time measures are used as a tool to gain a better understanding of the processing mechanisms inside the sentence during real-time comprehension. One possibility in collecting these new measures is that the matching directionality of sentence and motor response are taking place in temporal window where all dimensions of time are overlapping by coincidence.

The second hypothesis is that the window where these dimensions of time are converging is not a matter of overlapping temporal specificity but can be attributed to differences in the way the comprehender is interpreting first or third person perspective during sentence processing. By collecting separate time measures for both the preparation and execution of the action we can explore how perspective taking of the comprehender affects the time needed to successfully build the mental representation and execute the required motor response. Previous findings from the perspective taking literature suggest that during third person perspective the comprehender needs to be aware of who the self is in order to be able to imagine another person with the same mental representation (Keysar et al., 2000; Barr & Keysar, 2002). To take a third-person perspective, comprehenders have to be aware of what the agent intends to do before simulating the agent's action. The hypothesis is as follows: First person perspective or egocentric interpretations are generated automatically by the comprehension system suggesting that first person is a default generation. Third person perspective requires the comprehender to inhibit this egocentric interpretation to understand the context of the described sentence, devoting more attentional resources to constructing this mental representation suggesting that reaction times will be longer for third person perspective sentences.

The basis for Experiment 3 was developed from earlier ACE studies suggesting that by manipulating the timing of the visual cue we can affect the subsequent planning and execution of the motor response. Instead of manipulating the time at which the visual cue was presented thus modifying the motor response, this manipulation involved modifying the timing of the action described in the sentence itself. By modifying the timing of the action described in the sentence we can directly inspect online, real time sentence comprehension. The hypothesis for Experiment 3 is that if the sentence describes an urgent exertion of a pulling action (e.g. John quickly pulled the tablecloth) and a visual cue matching with a feature coding "towards", participants show greater facilitation than sentences describing exertion of force without the dimension of urgency (e.g. John pulled the tablecloth). Similarly if the sentence describes a non-urgent exertion of force (e.g. John slowly pulled the tablecloth) and a visual cue matching the towards feature participants exhibit slower motor responses than sentences describing exertion of force only. If we consider that language processing consists of complex, demanding neural circuitry then the relation between the perceptual representations describing urgency of the exerted action should differ from that of a perceptual representation describing exertion of force alone.

EXPERIMENT 1

In experiment 1, the question is whether we observe the ACE using a broader range of sentences. On each trial, participants heard sentences describing an action involving verbs of force, specifically pushing actions (e.g., "John pushed the door open") and pulling actions (e.g., "You pulled the tablecloth"). The auditorily recorded sentences were simultaneously presented with a visual cue that indicated response direction. The participant's task was to respond to the visual cue as soon as they understood the nature of the sentence. The visual stimulus cued the participant as to the required motor response (e.g. making a movement away from the body or making a movement toward the body). If the ACE replicates across this broader group of sentences there should be a match advantage, that is, when the sentence type (e.g.," John pushed the door open") matches the required motor response (e.g., arm movement away from the body) it should be easier for the participant to respond, thus creating a match advantage of sentence type by response direction.

Method

Participants. The participants were 80 introductory psychology students from Florida State University (20 in each of the 4 counterbalanced conditions). They received course credit in exchange for their participation. All participants provided written consent. Across the experiments, the data from a total of 3 participants was replaced due to low accuracy on the experimental task. Average response accuracy for the remaining participants was over 94%.

Materials. There were 24 critical sentences. The 24 critical items were further divided based upon the action described in the sentence, 12 sentences contained verbs expressing the action of "pulling" and 12 sentences contained verbs expressing the action of "pushing." Each sentence expressed a first-person perspective ("You pushed the door open") and a third-person perspective ("James pushed the door open"). An additional 24 filler sentences were selected, these fillers were sentences that expressed no directionality such as ("Jill sat on the bench"). The fillers items were sensible sentences that did not depict directionality of objects or events. All filler items are listed in Appendix C. Six additional sentences were generated to serve as practice items at the beginning of the experiment. Each counterbalanced list consisted of 54 trials. All sentences were recorded by a female speaker of American English using the freeware, open source software program Audacity 1.23 (Creative Commons attribution licensure), and played using Null soft Winamp 5.08. Item presentation and data collection was done running the commercial software package *E-PRIME 1.2* (Psychology Software Tools Inc.) The mean length of the critical sentences was 2488 ms (SD = 335 ms). All critical sentences are listed in the Appendix A. To ensure that participants would interpret the critical sentences as depicting motion in the direction that we had intended, we performed a norming study. After the completion of the experiment, the critical sentences were presented on a pen and pencil questionnaire to 40 randomly selected introductory psychology students. These participants were asked to judge what direction the action described in the sentence depicted, the choices were moving upward, downward, toward them, or away from them.

To ensure that sentences appeared equally often in all four critical conditions of the experiment (push sentences, away response (e.g. match item); push sentence, towards response (e.g. mismatch item); pull sentence, away response (e.g. mismatch item); pull sentence, towards response (e.g. match item), we created four counterbalanced lists on which a different set of 6 sentences were assigned to appear in each of the four critical conditions. Sentences were assigned to conditions randomly within the constraints that only 6 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 counterbalanced list, there was an equal number of first person and third-person perspective.

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. The participants were told they were going to hear a series of sentences, and that they should remember what each sentence meant as the experiment was going to end with a memory test (which was not actually administered). They sat with the computer keyboard situated on the desk at a 90-degree 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 the “Y” key on the keyboard. Participants were also told that at the beginning of each auditorily played sentence, the letter “P” or “Q” would appear on the computer screen.

Participants were instructed to respond as soon as they understood the nature of the sentence and saw the letter, they were to immediately release the "Y" key and press either the "P" or "Q" key (based on the letter presented on the screen). A "P" response would be a response towards the body or similar to a "pulling action", and a "Q" response would be a response away from the body or similar to a "pushing action." 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 auditory file. To reduce practice effects, participants first responded to 6 practice items. The practice items transitioned smoothly into the critical part of the experiment so that participants would not be aware of the change.

Design and Analysis. The dependent variable was the time required to press the "P" or "Q" button after the visual cue had been presented on the computer screen. The response cue was presented at the onset of the sentence; response time 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 ms) from the response time (such that a response of 0 ms would be a response made at the very end of the sentence).

The data were analyzed as follows. First, all incorrect responses (where participants pressed the wrong button) were removed from the dataset. Less than 6% of participant's responses were errors. Then, response times <100 ms and >2000 ms were removed from the analysis. The remaining data were further screened for outliers by removing all response times that were more than 2 standard deviations from each participant's mean response time in each of the four critical conditions (push sentence, away response (Match), push sentence, toward response (Mismatch), pull sentence, toward response (Match), pull sentence, away response (Mismatch). We elected to use 2 standard deviations as the cutoff based on similar ACE studies.

The data were then analyzed using a 2 (Match vs. Mismatch) x 2 Perspective (First person vs. Third person) x 4 (Counterbalance list: List 1, List 2, List 3, List 4) mixed factor analysis of variance (ANOVA) with counterbalanced list as a between-participant factor. Analyses were conducted across participants (denoted *F1*) and across items (denoted *F2*). Match vs. Mismatch, and Perspective taking are within-participants and within-items variables. All effects reported as significant are $p < 0.05$ unless otherwise noted.

Results. The results are presented in Table 1. In each experiment, the critical question is whether we observe the ACE. The ACE manifests itself as a main effect of Match vs. Mismatch such that responses are faster when the overall direction of the sentence matched the overall direction of the response. This effect was significant in the analysis by participants, but not in the analysis by items [$F_1(1,76) = 6.707$, $MS_e = 15{,}394$, $p < .012$; $F_2(1,23) = 1.951$, $MS_e = 20{,}953$, $p <. 176$]. There was a main effect of perspective taking such that first person perspective sentences were responded to faster than third person perspective sentences [$F_1 (1,76) = 3.209$ $MS_e = 17{,}198$, $p < .06$; $F_2(1,23) = 6.661$, $MS_e = 22{,}172$, $p < .013$]. Additionally, there was a hint of an interaction of Match x Perspective such that matches in first person perspective were faster than matches in third person perspective [$F_1(1,76) = 6.122$ $MS_e = 26{,}631$, $p < .016$; $F_2(1,23) = 1.991$, $MS_e = 41{,}989$, $p < .172$.]. Matches were responded to more quickly than mismatches in the third person perspective [$F_1(1,76) = 13.197$ $MS_e = 31{,}462$, $p < .001$; $F_2(1,23) = 3.586$, $MS_e = 62{,}841$, $p < .071$], but this effect was not significant in the first person perspective. Additionally, there was a significant interaction of Mismatch x Perspective such that mismatches in first person perspective were faster than mismatches in third person perspective [$F_1(1,76) = 6.807$ $MS_e = 30{,}375$, $p < .011$; $F_2(1,23) = 7.497$, $MS_e = 32{,}466$, $p < .012$].

Table 1. *Mean Response Times across Participants (in ms) and Proportion of Correct Responses for Experiment 1.*

Experiment 1				
	Match		Mismatch	
	RT	Accuracy	RT	Accuracy
1st Person	881	.97	8 81	.97
3rd Person	945	.96	1044	.96
Overall	913	.94	964	.94

Discussion

Experiment 1 results demonstrated a main effect of Match vs. Mismatch wherein the responses were faster when the overall direction of the sentence matched the overall direction of the response replicating previous studies demonstrating the compatibility effect. There was also a marginal interaction such that matches were faster than mismatches in third person, but this interaction was not significant for first person perspective analysis. While this interaction did not work out statistically the matches were faster than the mismatches in first person perspective.

One thing to note about this study is the comparative weakness of the results in the analyses across items. This hints at the possibility that there may be item-related differences in the study that is affecting the patterns of data that are observed. To address this possibility, we conducted a norming study in which participants were asked to read each sentence and indicate the direction of action (towards, away, up, or down) in which they imagined the action taking place in the sentence. The norming study revealed that a number of items were interpreted in a different manner by participants than originally specified by the researcher. This is one possible explanation for the weakness of the ACE effect in the analysis across items, and for the absence of the ACE in the first person perspective.

There was a significant effect of perspective, producing responses that were generally faster when the action in the sentence was described in a first person perspective (e.g. You pushed the door open) Vs. third person perspective (e.g. John pushed the door open). It may be that first person perspective is the default assumption when processing language, and as such it is easier to construct simulations for first person situations than for third person situations. This issue is addressed in Experiment 2.

EXPERIMENT 2

Experiment 2 used most of the same materials and methods as experiment 1 with the following modifications. First, we replaced some of the "bad" items from the first experiment with better ones. Second, experiment 2 was designed to investigate the mechanisms of motor planning and execution of the actions described in the sentence by separately inspecting the time required to prepare or comprehend the sentence and time needed to execute the motor response or key press by capturing two separate responses of the participant; the "Y" launch time and the participant's button press to the "P" or "Q" key. The first response time measure is the "Y" launch time which, is being defined as the time it took for the participants to release their index finger from the "Y" key. The "Y" launch time response time is different from experiment 1's response time in the sense that we separately measured the time it took for the participant to prepare the required action. The purpose of this approach was to examine if the "Y" launch time or preparation of the action described in the sentence significantly interacts with the perspective taking of the comprehender. The second response measure was isolating the time it took for the participant to press the "P" or "Q" key. The second response measure is defined as the response time of the arm movement to the "P" or "Q" key and was calculated by taking the overall response time of each trial and subtracting that from the "Y" launch time, which isolates the "P" or "Q" key response time. Does the comprehender rely on their default egocentric interpretation or first-person perspective and create a mental simulation of the action described in the sentence, faster than if the comprehender was processing a third person perspective sentence and needed to modify the default egocentric interpretation in effort to fully comprehend the sentence and execute the required motor response. If first person perspective is an easier mental representation to create than the reaction time differences reflected in both the planning and execution of the action should be faster than reaction times of third person perspective.

Method

Participants. The participants were 80 introductory psychology students from Florida State University that participated in exchange for course credit. Across the experiments, the data from a total of 6 participants was replaced, 4 due to low accuracy on the experimental task and 2 participants elected to terminate their participation before completion. Average response accuracy for the remaining participants was over 98%.

Materials. All materials were the same as in Experiment 1, except that 6 sentences were replaced by new items.

Procedure. The procedure was identical to that used in Experiment 1 with the following modifications. During the practice trials participants were presented with a block of 25 high and low tones to capture baseline motor responses. A high and low tone were played before the start of the practice trials so that the participant could clearly distinguish between what was referred to as "high" and "low" tone. In Experiment 2 we asked participants to press and hold the "Y" key until the participant had comprehended the nature of the auditorily presented sentence, then to make an arm movement and press the "P" or "Q" key on the 90 degree orientated keyboard. The "Y" launch time or preparation of action was calculated by subtracting the "Y" release from the visual cue onset time.

Design and analysis. The design was the same as that of Experiment 1 with the following modifications. The dependent variables are the time to press the "P" or "Q" key and the "Y" launch time. A separate analysis was done on the "P" "Q" response time and the "Y" launch time and as presented as two separate analyses in the results section. Response times <75 ms and >1450 ms were removed from the analysis as, we elected to use 2 standard deviations as the cutoff based on similar studies, as times more than 2 standard deviations from a subject's cell mean. The data was analyzed using a 2 Match vs. Mismatch x 2(Perspective: First person vs. Third person) x 4 (Counterbalance list: List 1, List 2, List 3, List 4) mixed factor analysis of variance (ANOVA) with counterbalanced list as a between-participant factor. Analyses were conducted across participants (denoted *F1*) and across items (denoted *F2*). Match, Mismatch, and Perspective taking are within-participants and within-items variables

Results. The results are presented in Table 2. In each experiment, the critical question is whether we observe the ACE. The "P" or "Q" response time manifests as a main effect of Match such that the time it takes for the participant's to physically respond with an arm movement and button press is faster when the direction of the sentence matches the direction of the response. This effect was significant by participants, and marginally so by items [$F_1(1,76) = 6.975$, $MS_e = 21,168$, $p < .01$; $F_2(1,23) = 3.182$ $MS_e = 5,804$, $p <. 08$]. The main effect of perspective taking and the interaction of Match and Perspective taking were not significant. There were no significant effects for the "Y" response time measure.

Table 2. *"P" "Q" Response Times across Participants (in ms) and Proportion of Correct Responses for Experiment 2.*

Experiment 2				
	Match		Mismatch	
	RT	Accuracy	RT	Accuracy
1st Person	360	.98	384	.98
3rd Person	373	.99	395	.98
Overall	367	.96	389	.96

Discussion

Again, Experiment 2 results demonstrated a main effect of Match vs. Mismatch on the "P" "Q" move times in that responses were faster when the overall direction of the sentence matched the overall direction of the response replicating previous studies demonstrating the compatibility effect. We do not see this replication in the "Y" launch times suggesting that preparation of the action does not interfere with the participant's ability to generate a mental representation of the described sentence. The execution of the action or the "P" "Q" move times seem to reliably facilitate or interfere with the participants ability to reconstruct the action described in the sentence, suggesting that while planning plays a role in constructing a mental representation this experiment does not demonstrate that it is an important measure to examine the mechanisms involved in preparation of the action.

There was also a significant effect such that matches were faster than mismatches for both first person and in third person sentences, suggesting that the "P" "Q" move times are a more sensitive measure than the overall response times used in Experiment 1. In this sense "P" "Q" move times or execution of the action by participant provides us with a more sensitive measure of the possible mechanisms behind how sentence comprehension interacts with execution of actions. The main effect of perspective was not significant overall.

EXPERIMENT 3

Experiment 3 was designed to investigate if urgency of action strengthened the perceptual representation of the pushing and pulling verbs. Experiment 3 used urgent and non-urgent adverbs coupled with the pushing and pulling action verbs to examine if the participant activates a perceptual representation that is sensitive to urgency of the action. The experiment was designed to further investigate how the dimension of time in which the comprehender activates perceptual information affects the overt motor response. More specifically, does an urgent goal directed action increase the speed of the comprehender's motor response when sentence direction and response direction match?

Method

Participants. The participants were 80 introductory psychology students from Florida State University that participated in exchange for course credit. Across the experiments, the data from a total of 7 participants was replaced due to low accuracy on the experimental task. Average response accuracy for the remaining participants was over 94%.

Materials. The materials were identical to those used in Experiment 2 with the following modifications; all the previously used sentences from Experiment 2 were re-recorded with adverbs that described an urgent or non-urgent time shift. For example an urgent action would be described in a sentence such as "John quickly pushed the box across the floor." A non-urgent action would be "John slowly pushed the box across the floor." The mean length of the critical sentences was 2493 ms (SD = 400ms). All critical sentences are listed in the Appendix B. The filler items were identical to the sentences used in Experiment 1 and 2, and did not depict directionality or urgency.

Procedure. The procedure was identical to that of Experiment 1.

Design and analysis. The design was the same as that of Experiment 1with the following modifications. Response times <100 ms and >2600 ms were removed from the analysis We elected to use 2 standard deviations as the cutoff based on similar ACE studies, as well as times more than 2 standard deviations from a subject's cell mean. The data were then analyzed using a 2 Match vs. Mismatch x 2 (time shift: Urgent vs. Non-urgent action) x 4 (Counterbalance list: List 1, List 2, List 3, List 4) mixed factor analysis of variance (ANOVA) with counterbalanced list as a between-participant factor.

Analyses were conducted across participants (denoted *F1*) and across items (denoted *F2*). Match, Mismatch, and Time-shift are within-participants and within-items variables. This analysis allowed for us to examine time it took for the participant to perform the action on the "P" or "Q" key.

Results. The results are presented in Table 3. There were no main effects of Match. Additionally, the main effect of verb was not statistically significant by subjects of items. There was a simple main effect between Mismatch x Time shift, such that the mismatches were faster with urgent verbs than with non-urgent verbs [$F_1(1,76) = 5.624$ $MS_e = 14{,}440$, $p < .02$; $F_2(1,23) = 9.267$, $MS_e = 4171$, $p < .006$]. There was a marginally significant interaction between Match vs. Mismatch x Time shift such that matches in non-urgent time shift were faster than mismatches in non-urgent time shift [$F_1(1,76) = 2.905$ $MS_e = 24{,}874$, $p < .09$; $F_2(1,23) = 3.147$, $MS_e = 11{,}575$, $p < .09$].

Table 3. *"P" "Q" Response Times across Participants (in ms) and Proportion of Correct Responses for Experiment 3.*

Experiment 3				
	Match		Mismatch	
	RT	Accuracy	RT	Accuracy
Urgent Adverbs	427	.97	400	.96
Non-Urgent Adverbs	403	.96	448	.96
Overall	419	.95	427	.95

Discussion

Experiment 3 results suggest a weak mismatch advantage since the responses were faster when the overall direction of the sentence mismatched the overall direction of the response, this weak mismatch is not statistically significant but worth noting, because it may be that the time-shift variable interacts with the ability to execute the action. The execution of the action or the "P" "Q" move times interferes with the participant's ability to reconstruct the action described in the sentence.

There was a significant interaction between Match x Time shift, where there was a match advantage for non-urgent verbs and a mismatch advantage for urgent verbs. One possibility for the mixed results is that changing the structure of the sentence to include adverbs expressing changes in the timing of the actions may have been interpreted as modifying other elements of the sentence; therefore the predicted effects did not occur. Another possibility is that because the adverb occurred relatively early on in the sentence (e.g. John quickly pushed the box across the floor), the effect of the time shift had already degraded by the time the participant was ready to respond.

GENERAL DISCUSSION

The results from these three experiments support general predictions made by the Theory of Event Coding (TEC) in that the activation of common action-relevant features during motor planning (e.g. towards movement) and sentence processing (e.g. towards sentence) is the mechanism that produces the ACE reported by Glenberg and Kaschak (2002). This activation of common action-relevant features during motor planning and sentence processing is also seen in Experiment 1 wherein sentences describing pulling actions are in close approximation to the directionality of a towards motor response, which suggests that sentences describing towards and pulling actions may be part of similar semantic network of actions that are drawing upon similar sensorimotor experiences. In encoding perceptual experiences, towards and pulling actions appear to instantiate similar knowledge substrates that reference these specific directionality-driven experiences. Experiment 1 represents an extension of the ACE; wherein compatible responses were faster.

Experiment 2 was designed to examine the mechanisms involved in the preparation and execution of the action described in the sentence by separately inspecting the time required to prepare or comprehend the sentence or “Y” launch time and time needed to execute the motor response or key press of the “P” or “Q” key. Experiment 2 results suggest that during the preparation of the action or “Y” launch time that the matching directionality of sentence and motor response are taking place in a window in which all dimensions are overlapping producing no reliably significant differences in preparation times for the overall match or mismatch or match by perspective. For the execution of the motor response or “P” “Q” key presses we demonstrate that there are significant differences in the way the comprehender is interpreting first or third person perspective during sentence processing. Perspective taking of the comprehender affects the time needed to successfully build the mental representation and execute the required motor response wherein matching sentence direction and response direction is faster in the first person perspective than third person perspective.

Possible explanations for no significant differences in the preparation of the action or “Y” launch time in Experiment 2 are: (1) that the task was examining a time window that was too small to parse apart reliably, given that the preparation of the action takes place on the order of a few hundred milliseconds, that the paradigm was not sensitive enough due to the complexity of the task (2) the preparation of the action is not reflective of any relevant process in building the mental representation (3) there was a confound between the items that actually caused the differences of interest.

The basis for Experiment 3 came from earlier ACE studies suggesting that by manipulating the timing of the visual cue we can affect the subsequent planning and execution of the motor response. Instead of manipulating the time at which the visual cue was presented, this manipulation involved modifying the timing of the action described in the sentence itself thus modifying the motor response. The results support the original hypothesis suggesting that the comprehender is faster to respond when sentence direction and response direction matches in sentences describing urgent actions vs. non-urgent actions. Also, participants are faster when sentence direction and response direction mismatches in sentences describing urgent actions vs. non-urgent actions. The perceptual representation constructed by the participant is sensitive to the urgency of the action described in the sentence in both the match and mismatch conditions suggesting that temporal dynamics described in action based sentences may be relevant above and beyond the basic ACE phenomena.

The data reported in this paper have shed some light on the constraints of the temporal dynamics that surround the activation and use of motor information during the processing of sentences about action. Additionally, the data further constrains the nature of the ACE, by reporting that similar categorical representations of direction reliably produce the compatibility effect. In order to develop a fuller understanding of these dynamics, it will be necessary to conduct studies using a broader range of paradigms, such as a lexical decision task, to tap into the specificity of categorically related directionality. Designs that specifically map onto task such that sentences about pushing and pulling actions should involve pushing and pulling response rather than towards and away key presses could be useful. Paradigms and designs that are more constrained will allow for further development of sensorimotor theories of language comprehension.

AUTHOR'S NOTES

I thank undergraduate students Divya Manjunath, Devona Gray, Gifty Abraham, Clayton Weiss for assistance with data collection.

APPENDIX A: HUMAN SUBJECTS APPROVAL FORM

Florida State
UNIVERSITY

Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2742
(850) 644-8633 · FAX (850) 644-4392

REAPPROVAL MEMORANDUM

Date: 6/21/2006

To:
Michael Kaschak
MC 1270

Dept.: **PSYCHOLOGY DEPARTMENT**

From: **Thomas L. Jacobson, Chair**

Re: **Reapproval of Use of Human subjects in Research:**
The Role of Memory for Specific Experiences in Language Comprehension

Your request to continue the research project listed above involving human subjects has been approved by the Human Subjects Committee. If your project has not been completed by 6/19/2007 please request renewed approval.

You are reminded that a change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must report to the Chair promptly and in writing, any unanticipated problems involving risks to subjects or others.

By copy of this memorandum, the Chairman of your department and/or your major professor are reminded of their responsibility for being informed concerning research projects involving human subjects in their department. They are advised to review the protocols of such investigations as often as necessary to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

Cc:
HSC No. 2006.0539 -R

APPENDIX B: HUMAN SUBJECTS INFORMED CONSENT

Informed Consent: Memory and Language Comprehension

I freely and voluntarily consent to be a participant in the research project entitled "Memory and Language Comprehension."

I have been informed that Dr. Michael Kaschak, an Assistant Professor in the Department of Psychology at Florida State University, has requested my participation in a research study at Florida State University.

The purpose of this research is to understand how people's memory and language processing systems work together during language comprehension.

My participation will involve one of the following (check all that apply):

_____ Reading short stories or sentences, and answering questions about them

_____ Completing a series of sentence stems

_____ Learning a made-up language

_____ Engaging in a problem solving task

_____ Taking a memory test for materials presented in the experiment

_____ Answering questions about my personality or responses to certain situations

The experiment will last between 30 and 60 minutes. My performance on the experimental tasks and responses to any questionnaires given will be confidential to the extent allowed by law. No individual results of the experiment will ever be reported.

The experiment does not in any way constitute a risk to me. I understand that I will receive course credit for this experiment.

My consent may be withdrawn at any time without prejudice, penalty, or loss of benefits to which I am otherwise entitled. That is, my grade in the course will not be affected if I choose to withdraw from the experiment, nor will I receive an experiment credit penalty. However, I will still be obliged to fulfill my experiment participation obligation for the General Psychology course.

I may contact Dr. Kaschak (kaschak@psy.fsu.edu) if I have a question about this project. If I have any questions about my rights as a participant in this research, or if I feel I have been placed at risk, I can contact the chair of the Human Subjects Committee, Institutional Review Board, through the Vice President for the Office of Research at 644-8633.

I have read and understand this consent form.

__________________________ ____________

Participant (signed) Date

____

Participant (please print)

If the experiment involves the use of personality questionnaires:

I understand that my participation in this experiment requires that I respond to items presented on a series of questionnaires that ask about characteristics of my personality. These items include (but are not limited to) questions about how I feel in certain life situations and how likely I am to experience certain emotions (e.g., sad, angry, anxious, happy). The responses provided on these questionnaires will be kept confidential to the extent allowed by law. Data collected in this study will be presented in aggregate; no reporting of data from individual participants will ever take place.

I understand that I will be asked to respond to personality questionnaires during this study, and give my consent to this procedure.

__________________________ ____________

Participant (signed) Date

____

Participant (please print)

If the experiment involves the recording of your voice:

I understand that my participation in this experiment requires my voice and speech to be recorded. I understand that the experimenters have taken steps to ensure the confidentiality of the recording, namely: identifying the recordings by participant number only, and not by name; keeping the recordings in locked cabinet to which only authorized lab personnel have access; and prohibiting the recordings from being taken outside the laboratory. In keeping with the standards of the American Psychological Association, the recordings will be kept for a period of 10 years, after which they will be destroyed.

I understand that I will be recorded during this experiment, and give my consent to this procedure.

__________________________ ____________

Participant (signed) Date

____

Participant (please print)

____

Name of person obtaining informed consent

APPENDIX C: CRITICAL ITEMS FOR EXPERIMENTS 1-2

Megan pulled the double braided rope.
You pulled the double braided rope.

John yanked the weeds from the flowerbed.
You yanked the weeds from the flowerbed.

Lisa tugged the metal chains.
You tugged the metal chains.

George pulled the handle on the door.
You pulled the handle on the door.

Martin yanked the emergency cord.
You yanked the emergency cord.

Joe tugged the strings on the puppet.
You tugged the strings on the puppet.

Dan pulled the tablecloth.
You pulled the tablecloth.

Jack yanked the ribbon off the gift.
You yanked the ribbon off the gift.

Jane tugged the sled through the snow.
You tugged the sled through the snow.

Gina pushed the grocery cart.
You pushed the grocery cart.

Larry hurled the shot put.
You hurled the shot put.

Kathy shoved the books off her desk.
You shoved the books off your desk.

James pushed the door open.
You pushed the door open.

Tom hurled the clothes into the washer.
You hurled the clothes into the washer.

Jenni shoved the tray of food.
You shoved the tray of food.
John pushed the table against the wall.

You pushed the table against the wall.

Rob hurled the empty beer cans.
You hurled the empty beer cans.

Jeff shoved through the screaming fans.
You shoved through the screaming fans.

John pushed the committee to accept his proposal.
You pushed the committee to accept your proposal.

Bill was shoved within an inch of her sanity.
You were shoved within an inch of your sanity.

Cody pushed the students to study for the exam.
You pushed the students to study for the exam.

Tracy pulled a dirty trick on her friend.
You pulled a dirty trick on your friend.

Brad tugged to make a decent living for his family.
You tugged to make a decent living for your family.

Jackie pulled her weight with the company.
You pulled your weight with the company.

APPENDIX D: CRITICAL ITEMS FOR EXPERIMENT 3

James pushed the door open.
You pushed the door open.

Kathy shoved the key into the door.
You shoved the key into the door.

Tom hurled the empty bottle at the intruder.
You hurled the empty bottle at the intruder.

Dan hurled the darts at the board.
You hurled the darts at the board.

Jackie pushed the dog into the cage.
You pushed the dog into the cage.

Bill shoved his friend into the pool.
You shoved your friend into the pool.

Joan shoved the dirty clothes into the closet.
You shoved the dirty clothes into the closet.

Larry hurled the javelin.
You hurled the javelin.

Laura pushed the chess piece.
You pushed the chess piece.

Tom hurled the baseball at the catcher.
You hurled the baseball at the catcher.

John pushed the button on the soda machine.
You pushed the button on the soda machine.

Joe shoved his opponent during the game.
You shoved your opponent during the game.

Jamie pulled the refrigerator door open.
You pulled the refrigerator door open.

Jill tugged on the locked gate.
You tugged on the locked gate.

Max yanked the chair from the student.
You yanked the chair from the student.

John pulled the angry player from his opponent.
You pulled the angry player from his opponent.

Jane tugged at a stuck drawer.
You tugged at a stuck drawer.

John was yanked out of school.
You were yanked out of school.

George pulled the handle on the door.
You pulled the handle on the door.

Jack yanked the dog's leash.
You yanked the dog’s leash.

Lisa tugged the car door.
You tugged the car door.

Martha pulled the brownies from the oven.
You pulled the brownies from the oven.

Bob tugged the desk into the room.
You tugged the desk into the room.

Jim yanked on the computer joystick.
You yanked on the computer joystick.

Adverbs were counterbalanced across all sentences

Urgent	Non-Urgent
Swiftly	Reluctantly
Quickly	Sluggishly
Rapidly	Lazily
Hastily	Slowly

APPENDIX E: FILLER ITEMS FOR EXPERIMENT'S 1-3

Jill sat on the bench.
You sat on the bench.

Jane injured her arm.
You injured your am.

Bob listened to the teacher.
You listened to the teacher.

Bill played a song on the guitar.
You played a song on the guitar.

George watched the football game.
You watched the football game.

Mike cleaned the dirty kitchen.
You cleaned the dirty kitchen.

Ralph made a paper airplane.
You made a paper airplane.

Colleen washed the dirty clothes.
You washed the dirty clothes.

Neil likes to play chess.
You like to play chess.

Tom enjoys watching the sun set.
You enjoy watching the sun set.

Ryan sets the table for dinner.
You set the table for dinner.

Jackie takes the trash to the dumpster.
You take the trash to the dumpster.

Jim is awarded a medal.
You are awarded a medal.

Martha enjoys cooking new recipes.
You enjoy cooking new recipes.

Ann decided to change jobs.
You decided to change jobs.

John coaches a youth soccer team.
You coach a youth soccer team.

Andrew has calculus quiz.
You have a calculus quiz.

Larry needs to finish writing the paper.
You need to finish writing the paper.

Dan drives to the grocery store.
You drive to the grocery store.

Kim is a psychology major.
You are a psychology major.

Mike enjoys reading suspense novels
You enjoy reading suspense novels.

Cari attends class every Monday.
You attend class every Monday.

Mary flips the coin in the air.
You flip the coin in the air.

Jackie is going to the beach.
You are going to the beach.

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BIOGRAPHICAL SKETCH

Education

- Bachelor of Arts, Molecular and Cellular Biology, University of Connecticut Honors Scholar Designation 2nd highest undergraduate distinction, May 2004
- Bachelor of Arts, Psychology, University of Connecticut Honors in the Major Designation, May 2004
- Masters of Science, Cognitive Psychology, The Florida State University, September 2007

Technical Expertise

Cognitive Software and Equipment 2004-Present

- Cognitive Science Software: E-prime 1.2, Psyscope X, Direct RT & Media lab, SPSS 14.0, Sigmaplot, Minitab, Excel, Brain Voyager

- Hardware: 1 Applied Science Laboratories Head mounted Eye tracker Model: 5000 CU 2 Head mounted Eye Link II binocular 500 Hz Integrated System 3 Functional Magnetic Resonance Imaging fMRI 3T Siemens Scanner

- Platforms: Windows XP, Apple G4 OS 9& OSX, DOS, Virtual PC 7.02 Apple G4 OS 9 & OSX, Intel-based Apple

Molecular and Cellular Technique and Software Applications 2002-2004

- Cell Biology Software: Improvision Openlab, Dynamic Image Analysis System (DIAS 3.2), time lapse recording, Apple Cinepak, QuickTime applications, Image J, and Canvas 9 Professional

- Advanced Microscopy: Confocal Microscopy (inverted Leica TCS SP2 integrated system), Zeiss Axiovert 200M microscope, ORCA ER camera (Hamamatsu), CCD High Resolution Microscope Camera CoolSnap Technology (Photometrics), Flow Cytometry (Becton-Dickinson FACScalibur Dual Laser Flow Cytometer) for non-mammalian analysis

- Platforms: Windows XP, Apple G4 OS 9& OSX

Behavioral Neuroscience Technique and Software Applications 2001-2003

- Neuroscience Software: SMART tracking system in conjunction with the Morris water maze and 12 arm radial maze
- Histology: rat tissue dissection, analysis slicing, mounting, staining of tissues
- Stereotaxic Surgery: cannula placement targeting medial septum for intraseptal infusion of cholinergic agents in rats

Research Fellowships and Grants

- McDonnell Summer Institute fellowship in Cognitive Neuroscience at Dartmouth 2005.
- Summer Research Fellowship (SURF) in Behavioral Neuroscience, University of Connecticut, 2003.
- Multimodal NeuroImaging Fellowship, Carnegie Mellon University and University of Pittsburgh Summer Fellowship, 2007.

Publications

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Kaschak, M.P., Borreggine, K.L. 2007 Temporal Dynamics of the Action-sentence Compatibility Effect. The Quarterly Journal of Experimental Psychology.

Presentations

- 47th Annual Meeting of the Psychonomic Society 2006
  Embodied Cognition as the Foundation for Cognitive Science: Action Planning and Language Comprehension, Michael P. Kaschak & Kristin L. Borreggine

Professional Affiliation

- Cognitive Neuroscience Society
- American Psychological Society
- Cognitive Science Society