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Modal Specific Context Varies Discourse Self-Relevance and Narrative Simulations

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Abstract

Perceptual symbols theory proposes readers simulate discourses perceptually. Pronouns and context modulate the simulation's perspective between the protagonist's internal perspective and an external onlooker's perspective. An experiment investigated if visual or tactile specific context-- the object property statements *the tomato is red* or *the tomato is cold*-- modulates the simulation perspective. Ninety-four undergraduates read discourses then verified discourse events in images. Experiment varied the pronoun, property modality, and image perspective. Modal-specific context did not interact with pronoun and image perspective to modulate simulation perspective as measured in task accuracy, $F(2, 154) = 1.638$, $p = 0.198$, but results still support perceptual symbol theory. Participants simulated narratives more richly if narrative was self-relevant.

Modal Specific Context Varies Discourse Self-Relevance and Narrative Simulations

> Father was in his study, playing with a loop of string.… I know where the string he was playing with came from. Maybe you can use it somewhere in your book. Father took the string from around the manuscript of a novel that a man in prison had sent him. (Vonnegut, 1998)

Reading appears to automatically evoke imagery or simulation, and various aspects of the narrative determine the simulation's perspective. Barsalou (2005, as cited in Brunye, Ditman, Mahoney, Augustyn, & Taylor, 2009) suggests that when a narrative describes an object, readers take the perspective of whatever character is interacting with that object. When people hear event descriptions, they move their eyes in the same direction of the described event's motion (Spivey, Richardson, Tyler, & Young, 2000). Borghi, Glenberg and Kaschak (2004) demonstrated that people's ability to access information about an object proportionally relates to the fictional distance between a narrative's protagonist and the object; the farther the object is from the character, then the less accessible the object is to the reader. Different deictic terms induce different behavioral responses; a simulation mechanism explains such results. Reading several sentences, people more slowly read and poorly recall statements that did not match the point of view of the preceding statement (Black, Turner, & Bower, 1979). People may exert more cognitive effort to comprehend such narratives, because they must continually change the perspective of their simulations. They may process language more easily if the perspectives were consistent. Brunye et al. (2009) instructed participants to read brief narratives containing a transitive action and then observe a image. Participants confirmed whether or not the image showed the described action (termed valid or invalid pictures, respectively). Overall, participants verify valid pictures more quickly when the image's perspective matches the sentence pronoun's suggested perspective. For example, after reading, "You are peeling a cucumber", readers more quickly confirm that the described action is occurring in a image when the event is shown from the agent's perspective (termed an internal perspective), as compared to an observer's (termed an external perspective; see Figure 1. This effect depends on two variables—the pronoun in the sentence subject and the narrative's description of the agent. If the pronoun is *you* or *I,* as compared to *He*, then participants tended to confirm internal images more quickly than external ones. If a preceding discourse context explicitly disambiguated the agent identity, then participants confirmed internal pictures more quickly only when the pronoun was *you*. Overall, the results suggest that readers simulate narratives with modal information (here, a visual perspective) and that the surrounding verbally provided context modulates this simulation. The present research investigates whether modal-specific context—information about how an object looks or feels—also modulates the perspective of the simulation.

Reading may or may not induce involuntary (not solicited in the task) imagery, depending on how the mind represents concepts. If the word representations do not involve their referents' perceptual or motor characteristics, then reading words should not necessarily evoke simulations. These are amodal. Amodal representation theories provide the foundation for powerful, formal explanations of many cognitive mechanisms, such as language comprehension. But these theories have several abstract weaknesses, and, as detailed below, recent neuroimaging and behavioral studies support modal representations. In many modal representation theories, the brain represents entities using the same neural structures used to perceive them. Language comprehension activates these neural structures. If reading activates modal representations and if representations in different modalities interact, then modal-specific context may affect the narrative simulations.

Representations

A representation is some physical state that stands for an object, event or concept (Smith & Kosslyn, 2007). For example, the words on a page, a photograph, the magnetic fields on a computer hard drive, and the neural connections in the brain could all be considered representations. Only intentional (serving created, formed or assigned on purpose) and information-carrying (i.e. a collection of letters, although a physical state, does not necessarily constitute a word) physical states are representations (Smith & Kosslyn). Although the present research investigates how people engage semantic knowledge, note that for language comprehension, conceptual knowledge must relate to semantic knowledge, because for language to effectively communicate, the sender and receiver must map language units to representations of things in the world (Vigliocco & Vinson, 2007). Conceptual knowledge and semantic knowledge may actually be one and the same or merely have a direct one-to-one mapping.

Word meaning representation theories fall into two categories (Vigliocco & Vinson, 2007). Holistic theories state that people derive word meaning from the comprehension of tightly interconnected and intelligible parts which contribute to the whole. The word "tiger" may be represented by the sum of all the aspects that might contribute towards the meaning of "tiger", such as *stripes*, *orange*, *jungle*, *fast*, *dangerous*, *animal*, etc. The representation is greater than the sum of its parts. Furthermore, as holistic theory, its parts are not used as parts of other meanings. In contrast, featural theories state that word meaning is derived from the collection of reusable components. The mind reuses a given word's defining components towards the meanings of other words. The representation of "tiger" and "spaceship" may both use the component *fast.* Generally, featural theories describe representations as propositions. The word “tiger” may be represented by the representation [STRIPES, ORANGE, THING, JUNGLE, FAST, ANIMAL, etc] that refers to the following features: *stripes*, *orange*, *jungle*, *fast*, *animal*. The exact representation format specifies the relations between the features. Note that while the primitives lists may look similar, the components of the holistic representation are not separable. Holistic theories focus on how words relate and may involve mechanisms such as semantic networks and semantic fields and images, but featural theories focus on the components of word meanings and include statistical patterns in neural networks and embodiment (Smith & Kosslyn, 2007). The present research shall focus on featural theories, which can utilize either amodal or modal representations (Vigliocco & Vinson).

Amodal Representations

Traditional theories of cognition posit that semantic memory is separate from the modal system of perception, action and introspection. The mind converts the modal representations of such systems into amodal representations for semantic memory and cognitive processes, such as reading (Barsalou, 2008). People derive meaning from amodal representations through their syntactic rules and manipulation (Chomsky, 1980, as cited in Glenberg & Kaschak, 2002). These symbols are amodal, because they neither contain nor use entities that describe a substance’s form. For example, people use the same word for chairs, whether speaking (a sound mode) or writing (a visual mode) about chairs (Glenberg & Kaschak); they represent the meaning of the word in the same way, regardless of its mode. Amodal symbols are inherently abstract and arbitrary (Glenberg & Kaschak). The word *chair* refers to an object type that affords sitting, not a specific token—a single, physical, particular entity, such as the chair in the researcher’s office. The word designates both big chairs and little chairs and is therefore not concrete. Similarly, the word shape (orthography) or sound (phonology) does not resemble an actual chair; the word *chair* does not physically or functionally relate to actual chairs.

Psycholinguists have largely adopted amodal symbols because they permit simple and powerful formal means for representing knowledge and can be easily implemented into artificial intelligence computer programs (Barsalou, 2008). Using amodal symbols, researchers simulate essential conceptual system functions such as representing tokens and types, making categorical inferences, combining symbols productively, representing propositions, and representing abstract concepts (Barsalou, 1999).

The mind might use amodal symbols during language comprehension by employing frames, semantic networks, or property lists (Smith & Kosslyn, 2007). Symbols could be combined into a frame(similar to a proposition), a structure of expression that specifies relations between symbols. The cake which is to the left of the gifts above some table might be represented by the frame ABOVE{[LEFT-OF(gifts, cake)], table}. The syntactic relations of the primitives dictate the meaning. Second, the symbols could be associated through a semantic network, where the symbols are nodes and the nodes connect to each other in a specific way. The exact manner of the connections represents meaning. Third, the cake might simply be represented by a list of all its properties.

If the mind uses amodal symbols, it may not simulate narratives with any perceptual characteristics. Because the perspective of a visual image is a perceptual characteristic, and this has been shown to vary as a function of linguistic input (i.e., Black et al., 1979; Brunyé et al., 2009; Ruby & Decety, 2001), the present research assumes the mind uses modal representations.

Reasoning Against Amodal Symbols

Psycholinguists can explain nearly any phenomenon using amodal symbols, post-hoc, but ideally amodal system mechanisms should also predict behavior (Barsalou, 1999). In other words, such amodal mechanisms can explain a phenomenon, because they were designed to explain the phenomenon. Recent implementations of amodal conceptual knowledge systems include the Latent Semantic Analysis (LSA) and the Hyperspace Analogue to Language (HAL), which have explained many phenomena without the researchers making many a priori assumptions (Burgess & Lund, 1997; Landauer & Dumais, 1997; both as cited in Glenberg & Robertson, 2000). LSA defines words using their co-occurrence frequencies with other words. It searched a 300 million-word corpus (a collection of texts) and recorded co-occurrences in a 10-word window. HAL defines words by their frequency within a semantic space, such as the first 2000 words in all encyclopedia articles. However, Glenberg and Robertson (2000) showed that sentences with nearly identical LSA vectors (meanings) could effect different behavioral responses, such as sensibility and envisioning ratings. LSA, therefore failed to solve Harnad's Chinese-Room argument (1990, as cited in Glenberg & Kaschak, 2002). The Chinese-Room argument posits that if left in a room with only a Chinese-to-Chinese dictionary, one could never fully determine the meaning of any single word (logogram or character). All unknown words would be defined by only more unknown words, and so on. Essentially, the argument states that a conceptual knowledge system needs modal primitives; the only way to understand a word is to eventually associate it with a perceptual experience. The mind does not use only amodal symbols.

Several other abstract arguments exist against amodal symbol systems. Glenberg and Robertson (2000) indicate how the interconnecting amodal symbols could cause a combinatorial explosion. A fully integrated symbol connects to a vast number of other symbols, possibly in multiple ways. Unfortunately, the mind can have multiple indirect connections between any two symbols, so such systems would have trouble accurately reflecting innovative relations. It must pursue a specific path between two symbols, when many exist. For example, in determining if one could effectively use a matchbox as a temporary umbrella then the following inferences could be made, bringing the wrong answer: (1) a matchbox is made out of cardboard, (2) cardboard is made of paper, (3) paper is used to make newspapers (4) newspapers can be used as a temporary umbrella, (5) a matchbook can be used as a temporary umbrella (11). Barsalou (2008) also emphasizes that amodal-symbol theories poorly explain how cognition uses and interacts with perception and action. He also claims that little neuroimaging evidence confirms the physical existence of amodal symbols in the brain and that while amodal symbol systems (artificial intelligence programs) can duplicate nearly any psychological phenomenon, neuroimaging has not yet proven that the brain actually uses amodal symbols. If the brain does not use amodal representations, then perhaps it uses modal symbols.

Modal Representations: Perceptual Symbols

Grounded cognition theories, unlike amodal theories, assume the act of knowing directly uses perceptual primitives, such as through simulations, in situated action and possibly from bodily states (Barsalou, 2008). Grounded cognition describes conceptual knowledge units in two different ways (Borghi, 2005). Glenberg's (1997, as cited in Borghi) research states concepts may be either neural networks of potential action or perceptual symbols, which are concrete, modal and analogical symbols based on the same brain state as when it perceived the referent. Both explanations are featural representations, not holistic (Barsalou, 1999). While the former proposition suggests that the cognitive system functions to facilitate action in specific situations (and both propositions may be true), this paper shall focus on perceptual symbols, but will mention motor resonance, a parallel grounded cognition concept (Barsalou, 2008; Barsalou, 1999; Borghi). If the mind represents concepts and word meaning through perceptual symbols, then it may simulate narratives with perceptual characteristics.

The mind transduces perceptual states—an "unconscious neural representation of physical input" and an optional conscious experience—into perceptual symbols (Barsalou, 1999, p577). It extracts a subset of this perceptual state via selective attention and stores the subset in long-term memory. Selective attention isolates aspects of perception, specifically features, "meaningful sensory aspects of a perceptual stimulus" (Smith & Kosslyn, 2007, p162). When people attend to features, they are more likely to store those perceptual components in long-term memory (Craik & Lockhart, 1972; as cited in Barsalou). Perceptual symbols can originate from any sensory modality, proprioception, and even introspection (Barsalou). Perceptual symbols do not exist in amodal theories, because such theories assume perception's elements are unique from cognition's elements.

Simulations

Once the mind has created perceptual symbols, it activates perceptual symbols to induce simulations, which become the primary cognitive mechanism (Barsalou, 2008). A simulation is a "reenactment of perceptual, motor and introspective states acquired during the experience with the world, body, and mind" (Barsalou, p618). The neural areas associated with perceiving a given modality also represent that modality during simulation, but the simulations can be multimodal (Barsalou; Zwaan & Madden, 2005). Amodal theories typically engage concepts through propositions, and do not use the same neural mechanisms as perception. The representation for apple may include its shape, taste, color, and texture, even if separate neural areas simulate these various modalities. Barsalou (1999) explains that people use neural networks symbolically, through simulation. The mind executes both deliberate and unconscious simulations (differentiated by being within or not within working memory). Just as selective attention specified certain features to become perceptual symbols, simulations do not require completely replicated neural activity; entities may be partially simulated. Simulating certain features may necessitate simulating others (simulating shape may automatically simulate orientation), but this coupling of features may be unconscious. Different processing channels for different visual components (shape, color, movement, orientation) supports the componential nature of grounded cognition (Barsalou, 1999).

Perceptual symbols and neural networks behave similarly; connections between and within entities can weaken over time, strengthen through co-occurrences, and inhibit others. Their featural nature and neural network behavior makes them similar to amodal symbols. Perceptual symbols' dynamic character allows them to be indeterminate or not specific to only one individual real world conception. For example, perceptual symbol X created from experiencing Y can stand for or be a part of representing non-Y referents. This distinguishes perceptual symbols from being picture-like, exact recordings of their referents. A *tiger* perceptual symbol may specify a striped animal, but not necessarily an exact number of stripes. The stripes perceptual symbol could, at a conscious level, be blurry or a mere pattern of stripes. Neurons could code individual concept features, such as the color but not the shape of a tiger (Barsalou, 1999). In contrast, a given amodal symbol can represent different real-world entities, because they are abstract.

The mind, using perceptual symbols, creates simulators, which manifest concepts for cognitive mechanisms (Barsalou, 1999). Since words are learned through perception, they have their own perceptual symbols and associate with their referents through operant conditioning. For example, after learning about cats and developing perceptual symbols for cats, one might then learn about the word *cat*. Through experiencing other entities using the word *cat* while pointing or picture a cat, one will develop perceptual symbols for the word *cat* (aurally and visually) and associate it to actual cats. The *cat* concept, as manifested through a simulation, might be partial, sketchy, or biased, but cognitive mechanisms can still use it (Barsalou, 1999).

Motor Resonance

A parallel idea to perceptual symbols in grounded cognition is referential motor resonance, activation of the motor system in response to the content of communication (Fischer & Zwaan, 2008). For example, upon hearing or reading the word *kick*, the leg motor system engages (without overtly moving the leg; Hauk, Johnsrude, Pulvermuller, 2004). The idea considers how the mind forms and uses action representations. Zwaan and Taylor (2006) posit that language comprehension incorporates or even requires motor system activity. Iverson and Goldin-Meadow (1998, as cited in Fischer & Zwaan) discussed how people gesture (a form of overt motor resonance) even towards those who cannot see the gestures (such as a phone call recipient) and how even the blind gesture during speech production. Spivey and Geng (2001, as cited in Fischer & Zwaan) documented that when participants look at a blank wall and listen to discourse, they fixate on the same position on the wall when they hear about a given object as when they first heard about the object. Other iconic gesturing (such as moving hand upward when conveying an ascending elevator) has shown to be pre-linguistic, thus operating a conceptual level (Vigliocco & Vinson, 2007). Motor resonance plays a role in this research because, (1) as detailed later, reading about action appears to initiate action simulations and (2) modal specific information may determine fine motor control.

Indexical Hypothesis

The indexical hypothesis explains how language comprehension uses perceptual symbols in three phases (Glenberg & Kaschak, 2002). First, the mind maps perceived words and phrases to their perceptual symbols (Barsalou, 2008; Glenberg & Kaschak). Then it analyzes, via simulation, to derive their affordances (Glenberg & Robertson, 2000). These are “offerings of nature”, or rather a relationship between an agent and his environment and an action (Gibson, 1979, p18). For example, a footstool affords an adult standing to help the adult reach a higher position. A toddler might also use the footstool in this manner, but note that the footstool more ideally affords the toddler sitting because the toddler is smaller. Gibson believes that people can directly perceive affordances and because perceptual symbols analogically describe real entities, therefore people can understand novel actions (i.e. actions that the person does not know from lack of experience or because the action is innovative; Glenberg & Kaschak). For example, one can comprehend “Hang your coat on the vacuum cleaner”, even if this interaction is novel, because the vacuum cleaner representation specifies how its narrow, sturdy, upright shape affords a flexible piece of cloth. In the last indexical hypothesis phase, the sentence syntax implies perceptual symbols’ interactions. *I kicked the goalie the ball* takes a Subject-Verb-Object1-Object2 construction. Any sentence taking this construction probably means that the subject transfers Object2 to Object1. One can comprehended “I crutched the goalie the ball” because it implies an object transfer and because the crutch perceptual symbol includes information about how as a long, solid implement, it can strike and propel a ball through space. Glenberg and Kaschak assume people learn syntax construction meanings through operant conditioning. In the present research, the indexical hypothesis predicts people will map words of modal properties (e.g. *cold* or *red*) to their perceptual symbols, initiating simulations of those concepts. The reader should then combine these simulations as determined by the syntactic construction of the sentence. The indexical hypothesis entirely assumes that people use modal, rather than amodal, representations.

Neuroimaging Support for Modal Representations

Neuroimaging studies show that motor and perceptual brain areas activate during language processing (Martin, Ungerleider and Haxby, 2001, as cited in Borghi et al., 2004). Reading body-specific action words activates areas in the fronto-central cortex somatotopically (Shtyrov, Hauk, & Pulvermuller, 2004, as cited in Fischer & Zwaan, 2008). A mass of evidence suggests specific neurons or groups of neurons are activated during perception of specific features, so activating a group of feature detectors may represent a specific concept (Smith & Kosslyn, 2007). Activating certain feature detectors parallels perceptual symbols' proposed componential nature. Warrington and Shallice (1984) suggest that because patients with different brain lesions exhibit different category-specific deficits in identification tasks (i.e. identifying inanimate but not living objects, visual but not verbal entities), the mind may organize semantic knowledge categories by location. Several theories partially explain these so called category-specific deficits, but the deficits may depend less on semantic categories, then factors such as visual complexity, familiarity and name frequency, among others (Cree & McRae 2003). Similarly, Gainotti (2006) indicates that these deficits are a complex function of semantic and episodic memory acquisition, the format of representations and their organization. But, more importantly, he also states conceptual knowledge draws from the sensory-motor system, and our perceptual mechanisms may uniquely watermark the conceptual knowledge representations which came through their acquisition process.

Mirror Neurons

Neuroimaging studies with high spatial-resolution suggest even stronger evidence for perceptual symbols. Single cell recording in macaque monkeys demonstrates that specific neurons fire both when action is performed and when a similar action, performed by an experimenter or conspecific is observed (Di Pellegrino, Fadiga, Fogassi, Gallese, & Rizzolatti, 1992; Gallese, Fadiga, Fogassi, & Rizzolatti, 1996; Rizzolatti, Fogassi, & Gallese, 2001; all as cited in Fischer & Zwaan, 2008). These mirror neurons are in the ventral premoter area F5 and the prefrontal and inferior parietal cortex. The macaque's mirror neurons ignore perspective, but have other constraints. Only transitive actions, where the agent, action and patient were present, activated the neurons. Later studies showed mirror neurons activate even if the observer merely believes the patient is present (a screen occluded the suggested patient) and if the observer merely hears the action (Umilta et al., 2001; Keysers et al., 2003; Kohler et al., 2002; all as cited in Fischer & Zwaan). More generally, Tootell, Silverman, Switkes, and Valois (1982, as cited in Smith & Kosslyn, 2007) found that monkeys' V1 area of the occipital cortex activated analogically to visual stimuli. Humans may also have mirror neurons. Human mirror neurons appear to be somatotopically organized, and studies have located some in Broca's area, which is homologous to macaque's F5 area (Aziz-Zadeh, Wilson, Rizzolatti, & Incoboni, 2006; Buccino et al. 2001; Gazzola, Aziz-Zadeh, Keysers 2006; all as cited in Fischer & Zwaan). For example, watching videos of both transitive and intransitive actions and seeing mere pictures of verbal and non-verbal lip postures activated specific neurons (Fadiga, Craighero, & Olivier, 2005; Urgesi, 2006; all as cited in Fischer & Zwaan). If specific areas partially reactivate during action observation, then perhaps these are the physical manifestations of perceptual symbols.

Although, the spatio-temporal resolution and task demands cannot entirely dismiss the above neural activation as merely epiphenomenal and humans not have mirror neurons, behavioral evidence also counters the existence of amodal symbol systems, while suggesting reading activates visual and motor simulations.

Language Comprehension through Visual Perceptual Symbols

Language comprehension can evoke modal representations. Readers simulate narratives perceptually and motorically (Fischer & Zwaan, 2008; Glenberg 2007). After reading narratives, readers confirm object pictures as narrative-relevant more quickly if the pictured object's shape matches the shape suggested by the narrative (Zwaan, Stanfield, & Yaxley, 2002). For example, people are faster to confirm that an eagle is mentioned in the sentence *The ranger saw in eagle in the sky* if the probing picture shows an eagle with its wings spread, rather than a stationary eagle. Stanfield and Zwaan (2001) showed how people respond differently to propositionally similar sentences. For example, *John pounded the nail into the floor* and *John pounded the nail into the wall* can be represented propositionally as [Pounded [John, Nail]], [In [Nail, Floor]] and [Pounded [John, Nail]], [In [Nail, Wall]], respectively. Participants read the sentences and then confirmed whether or not following pictures contained sentence-relevant objects (e.g. nail). Since they responded faster when the object's pictured orientation matched the orientation implied by the sentence, the authors concluded that readers must represent the orientation of the nails in the respective sentences differently, even though the propositions do not carry any nail orientation information. Narratives also initiate spatial relationship simulations. When verbally exposed to an object's two parts (e.g. a body's *foot* and *head*) simultaneously on a screen, readers more quickly judge the stimuli's semantic-relatedness if the word positions iconically reflect the whole object (e.g. *head* is presented above *foot*; Zwaan & Yaxley, 2003). Language comprehension does appear to evoke spatial property simulations (Rinck & Bower, 2004, as cited in Barsalou, 2008) and simulate narratives from specific perspectives (Spivey et al., 2000, as cited in Barsalou, 2008). Indeed sentence pronouns have been found to modulate these simulated perspectives (Brunye et al., 2009; Ruby & Decety, 2001, as cited in Brunye et al.).

Norman and Rumelhart (1975, as cited in Borghi, et al., 2004) stated amodal symbols serve semantic networks and that the number and sequence of relations between their amodal symbols analogically reflect spatial relations between object parts. However, in a linguistically presented object-part verification task, object information accessibility depended also on functional relations and spatial context (Borghi et al.). In this research, participants read sentences that implied the reader was in a certain location (e.g. *You are fueling a car*). They often more easily access object parts (e.g. *tail lights*) that are further from the protagonist's suggested position (e.g. outside of a car) than another part (i.e. *backseat*) if the parts are functionally related to the narrative's context (i.e. tail lights, are more functionally related, because they are outside of the car or more closely related to fueling than a backseat; Borghi et al.). Even if parts are equidistant from the agent's location (i.e. trunk and steering wheel with respect to fuel door), participants more quickly confirm parts that are in the same location (i.e. trunk is outside of the car) than parts in a different location (i.e. steering wheel is inside the car).

Overall, the behavioral evidence supports the existence and activation of perceptual symbols for comprehending language, particularly visual perceptual symbols. People simulate narratives visually from specific perspectives and simulate entities with specific shapes, orientations and spatial relations. But simulations can also focus on the functional aspect of objects. For instance, participants can complete a lexical decision task faster if a probe object shares affordances with the preceding object (e.g. *piano* and *typewriter*; Myung, Blumstein, & Sedivy, 2006, as cited in Fischer & Zwaan, 2008). In other words, reading object words that are visually dissimilar but manipulated similarly (e.g. a piano and a typewriter) facilitates a lexical decision task. Therefore simulations are specific to how an object is manipulated. Simulating based on manipulation method supports how reading engages the motor systems covertly.

Reading Engages the Motor System

The action compatibility effect (ACE) demonstrates how reading activates motor representations (Glenberg & Kaschak, 2002; Borghi et al., 2004). In Glenberg & Kaschak's study, participants confirmed sentences as sensible by moving their hand from a start position to a proximal button or a distal button. When the implied direction of a sentence (e.g. *Close the drawer* implies moving distally, pushing a drawer) opposes the response direction (here, pressing the proximal button; pulling the hand), participants tend to respond more slowly than when the implied direction and response direction are congruent. Both left- and right-handed readers are susceptible to the effect. Participants demonstrated ACE for imperative sentences (e.g. *Close the drawer*), concrete object transfers in the double object and dative constructions (e.g. *You handed Courtney the pizza*, *Andy delivered the pizza to you*, respectively), and abstract entity transfers (e.g. *Liz told you the story*). Amodal symbol theories posit that abstract transfers should not involve planning and executive action mechanisms (the separation of conceptual knowledge and action) so, if the mind uses amodal symbols, then reading should not affect the response action pattern. Reading sentences that imply a perspective, but no action, also cause the ACE (e.g. You are facing a car; Borghi, Glenberg, Kaschak, 2004). Zwaan and Taylor (2006) showed that when participants rotate a knob to advance through sentence segments about agents rotating objects, they rotate the knob more slowly if the actual knob's rotational direction opposed the fictional knob's direction (Fischer & Zwaan, 2008). Boulenger et al. (2006) demonstrated reading motion words can interfere or facilitate action, depending on the timing. In this research, participants made a reaching motion and if they saw an action word appear on a screen, they continued the motion, otherwise (i.e. they see a non-action word) they returned to the start position. If the action word appeared 200 ms after motion onset, the response was delayed. If the action word appeared 550-580 ms before onset, the response was facilitated.

Finer motor control, such as responding with either a precision or power grip, also depends on the same representation system as words. People judge whether objects (presented as pictures or words) are artificial or natural more slowly when the response contrasts with how the object would normally be held (Tucker & Ellis, 2004). Reading object words referring to differently sized objects (e.g. *grape* versus an *apple*) interacts with categorization task responses such as picking up differently sized wooden blocks (Glover, Rosenbaum, Graham, & Dixon, 2004). Even in Italian, the words indicating size evoke analogically similar hand gestures (Gentilucci, Benuzzi, Bertolani, Dapratii, & Gangitano, 2000).

Motor resonance also demonstrates the tight link between conceptual knowledge and word meaning. Reading or hearing motion words activates the primary motor cortex (Tettamanti et al., 2005, as cited in Vigliocco & Vinson, 2007). Transcranial magnetic stimulation of the brain's hand and leg motor areas interferes with categorizing hand-related and leg-related words (Pulvermller, Hauk, Nikulin, & Ilmoniemi, 2005, as cited in Fischer & Zwaan, 2008). This occurred in only the left hemisphere, the general language comprehension location.

The indexical hypothesis suggests ACE occurs because understanding the sentences taps into the action planning and execution cognitive mechanisms. Moving the hands and locating the buttons and comprehending the sentences used the same mechanisms, and thus the response was delayed. If representing language and action rely partially on the same mechanisms, then action should also affect language comprehension, perhaps a reverse ACE.

Klatzky, Lederman, & Matula (1993, as cited in Fischer & Zwaan, 2008) demonstrated that specific hand postures primed verb-noun pair comprehension. For example, holding the hand slightly open facilitates comprehending *squeeze-tomato*, but holding the hand in a pinching posture facilitates *throw-dart* comprehension. Tucker & Ellis (2001) showed that prehensile motions interfere with object classification if the motion does match the way the object should be held (e.g. a precision or a power grip). The relationship is not limited to the hands. Preparing verbal utterances has a detrimental effect on the visual perception of words (Hommel & Musseler, 2006, as cited in Fischer & Zwaan). Overall, motor resonance may influence language comprehension. The aforementioned examples of differential brain activation during language comprehension and language-action interrelations suggest that the mind automatically retrieves action representations during sentence comprehension (Vigliocco & Vinson, 2007).

Does Reading Activate Tactile Simulations?

Reading clearly activates both visual and motor simulations, and action interacts with language comprehension. For reading tactile object descriptions to modulate the perspective of visual simulations, reading must initiate tactile simulations, directly or indirectly. The author considers three reasons this may occur. First, precise motor control relies partially on tactile information. An object's flexibility, elasticity, compressibility, etc, afford different interactions. For example, one holds a hard rock differently than a squishy tomato. So when reading about actions engages motor simulations, it, or the motor simulations, may also activate tactile simulations. This may be especially true when the narrative explicitly specifies the direct object's tactile properties. Furthermore, people not only modify their interactions based tactile information, they also acquire tactile information through action. Determining whether an object is hot or cold, hard of soft, generally requires direct contact with the object (although one can also infer such properties by observing others contacting the object). Determining whether an object is smooth or rough can be inferred through vision, but when achieved through touch, the interaction most likely involves moving the hand across object surface, rather than merely touching it. Because of this relationship between action and tactile information, when the mind simulates motor information during reading, it may also simulate tactile experiences.

In the second possibility, reading about objects, their tactile properties, or both may directly simulate tactile information. The indexical hypothesis, as described earlier, posits that representing word meaning relies on mapping the word's orthography and phonology to its perceptual symbol (e.g. associating the word *soft* with perceiving *soft*). This largely assumes a tight coupling between word meanings and tactile representations. Imagery (simulation) and perception may have a common neural system and associated areas integrate across systems of perception, imagery and knowledge (Crammond, 1997, as cited in Barsalou, 1999). Higher order areas of convergence may also integrate across modalities (Smith & Kosslyn, 2007). If an object's tactile representations are directly associated with the object's overall conceptual representation, then the reading about objects, and their tactile properties, may activate tactile simulations. Studies show that while representing object conceptual knowledge, the same areas concerning object's properties also activate (Martin, 2007, as cited in Barsalou, 2008). While Gibson (1979) may suggest that people directly perceive affordances, people may need both visual information and conceptual information to appropriately interact with objects (Borghi, 2005). Some objects have many affordances. While one can hold a small rock in a limited number of ways, one can manipulate a bicycle in a vast number of methods and locations. Determining which affordance to use must require integrating information about the perceived affordances with past experience and ideas of how the object functions. Also, context-specific goals certainly modulate interaction. For example, when holding a glass, the grip may be firm and whole to assure that it does not slip away, but while cleaning a glass, the grip may be a strong precision grip to expose most of the glass to some cleaning implement. Furthermore, not all affordances fit with the correct usage. A knife can be pinched, but should be used by a power grip, on a specific portion of the knife body. However, none of the behavioral or neuroimaging evidence reviewed here supports the mapping of words to tactile perceptual symbols specifically and modal representations' componential nature permits selective feature simulation. Perhaps reading may simulate tactile experiences for a different reason.

Third, reading may initiate tactile simulations via visual simulations, because (1) people can use object representations in one modality to recognize the same object in a different modality and (2) specific visual representations affect action, as mentioned earlier. Modality specific representations may inform and influence object simulations in different modalities. Studies of cross-modal recognition investigate how examining an object in one modality permits recognizing the object in another modality. For example, participants might be asked to handle an object in the dark and then be asked to recognize it among other objects in a picture. Adults perform this task successfully (Bushnell & Baxt, 1999). Infants and children ranging from 2.5 to 8 years can accurately recognize objects in one modality, after observing them in a different modality (Bigelow, 1981; Morrongiello, Humprey, Timney, Choi, & Rocca, 1994; all as cited in Bushnell & Baxt, 1999). Also, specific visual representations may directly affect action. People confirm pictured entities as objects more quickly and accurately when the responding hand is on the same side as the object's affordance (e.g. the handle of a mug being on the left or right side of the picture; Tucker & Ellis, 2001). The experimenters observed the same effect when participants confirm whether an object is right side up or upside down (Tucker & Ellis, 2004). Clearly, perceiving pictures evokes sensorimotor representations, so perhaps simulating visual perceptions also evokes sensorimotor representations.

Assuming reading activates tactile simulations, these tactile simulations should encourage perspective-specific visual simulations through any of the three methods outlined above. Since an object's tactile properties defines its affordances, then reading about tactile information should clarify the reading-induced motor simulation. This motor simulation will be egocentric, from the reader's perspective, because acquiring tactile information can only be done through direct experience.

The Present Research

The present research investigates whether reading modal-specific information influences the visual simulation's perspective during the comprehension of action sentences. Conceptual knowledge representation, and thus semantic knowledge, may contain modal information, and reading sentences appears to access this modal information automatically. Participants in the following experiment read narratives about simple actions and were confirmed whether or not following pictures demonstrated the action. Pictures showed hands, holding objects, from either the agent's perspective or an observer's perspective.

Tactile information should facilitate task performance when the discourse suggests an internal perspective (Pronoun is *You*) and preceded an internal perspective picture, because tactile information should evoke egocentric simulations. When both factors guiding simulation (pronoun and modality) suggest an internal perspective, then seeing an internal perspective picture should be easy to evaluate (in comparison to an external perspective picture). Accuracy should increase and response time should decrease. The researcher likewise predicted these scenarios (You, Tactile, Internal and You, Tactile, External) would effect better and worse performance metrics, respectively, than their Visual counterparts.

When participants read external perspective suggesting narratives(I, He) with tactile information then see an external perspective picture, they should perform less accurately and more slowly than their visual counterparts, because the tactile information may induce an egocentric perspective to conflict with the picture stimuli. The effect may be slight, because, as stated earlier, some tactile properties can be discerned by watching others touch objects. Brunye et al. (2009) found that when reading external perspective suggesting narratives(I, He), participants are slower to respond to an internal perspective picture than an external perspective picture. The researcher expects this same effect, even when the narrative includes tactile information.

Although Brunye et al. (2009) did not report gender differences, the original study did show data variation as a function of gender. Though these patterns did not reach significance, they suggested that females were more inclined to immerse themselves from an actor's perspective relative to their male counterparts. In the present study, reading tactile or visual object descriptions further specifies the elements characterizing mental simulations. The higher degree of specification, which may include specifying the agent's hands, may cause participants to react differentially to the pictured agent's *male* hands. Female participants may have to overcome the subtle gender difference and attempt to focus on the event action; such a process could hinder performance.

Method

Participants

Ninety-four English speakers (34 male; *M* age= 19.3 years) participated in the study. Forty-four participated as part of a requirement for their Tufts University psychology class; others participated for monetary compensation.

Materials

Event descriptions

Twenty-four discourse scenarios were modified using materials from Brunyé et al. (2009, Exp. 2). Each scenario focused on a unique object and was three sentences long; for the present study, these scenarios were modified to include a fourth final sentence. The first sentence described the agent by age and occupation (i.e., [A] [L] *a* [X]-*year old* [O].; e.g., *I am a 30-year old deli employee.*). All auxiliary verbs ([L]) varied to agree with their primary argument, the agent (i.e., *I am*, *You are*, *He is*). The second sentence repeated the agent [A] and stated an occupation appropriate goal (i.e., [A] [L] [G]; e.g., *I am making a vegetable wrap.*). The third sentence (termed the action sentence) described the agent conducting a transitive action with a temporal marker emphasizing the progressive aspect (i.e., *Right now* [A] [L] [V] *the* [O]; e.g. *Right now I am slicing the tomato.*) The fourth sentence (termed the property sentence) assigned either a tactile or visual property to the object of the transitive action (i.e., *The* [O] *is* [P]; e.g., *The tomato is cold.* or *The tomato is soft.*) The agent descriptions were purposely designed to not accurately reflect the participants, who were all Tufts University undergraduates.

A pilot study was conducted to select visual and tactile adjectives for use in the property sentences. Twenty-three Tufts University students rated a preliminary list of 109 unique object-property combinations. For each sentence, participants were asked to complete the statement "The knowledge in the sentence can be achieved..." by choosing one of five options on a continuum ranging from 1 (Only through vision) to 5 (Only through touch). Ratings for each property were averaged for each object, and the visual property with the lowest rating, and tactile property with the highest rating, was chosen. To ensure that the selected visual and tactile properties were similarly sensible and easy to imagine, we conducted a second pilot study using ten additional Tufts University students. Participants rated each sentence in response to two questions, “How much sense does this sentence make?” (1= “No Sense”, 7= “Complete Sense”), and, “How easy is it to imagine what is stated in this sentence?” (1= “Very Difficult to Imagine”, 7= “Very Easy to Imagine”). Ratings confirmed that sensibility and ability to be imagined were similar across the two property modalities. The final list of adjectives and their associated objects and verbs is presented in Table 1.

Five abbreviated practice scenarios were constructed in addition to the 24 experimental scenarios. These consisted of only two sentences, the action and description sentence (the scenarios did not describe the agent or an occupation related goal). All occupation-appropriate goals, actions, objects, and properties were unique across the practice and experimental scenarios.

Event images

Pictures were taken from Brunyé et al (2009). Four pictures were assigned to each of the 24 experimental scenarios. Each picture of a set related to the action sentence of their assigned discourse, but varied by validity and perspective. Continuing from the above examples, a set of four pictures showing an agent’s hands and a tomato were assigned to the tomato scenario. A given picture showed the action either being performed (valid) or not (invalid) and showed it from either an external or internal perspective (see Figure 1). Valid pictures depicted the event mid-action. Invalid pictures depicted hands holding the relevant object and tool (e.g., a tomato and a knife; if necessary, not all transitive actions required a tool, such as peeling), but the hands, tools, or both are not applied to the object. External perspective pictures depicted an ‘onlooker’ perspective facing the front of the agent. Internal perspective pictures depicted the agent’s egocentric perspective. Overall, the four pictures exhibited the four possible combinations of validity and perspective. The number of object-relevant pictures totaled 96. An additional six pictures were taken from Brunyé et al (2009). These pictures, termed null pictures, showed hands holding objects and tools irrelevant to any of the 24 scenarios. All of the null pictures were inherently invalid and the set of null pictures evenly represented external and internal perspectives; null images were included to ensure that participants were indeed matching images to described actions rather than merely answering 'yes' to all action photos (regardless of relevance to the described action). All images depicted the action from approximately 40" at a 35˚ downward angle. Fourteen more additional similar images were assigned to the practice block.

Procedure

The procedure implemented a 3 (Pronoun: *I*, *You*, *He*) x 2 (Modality: tactile, visual) x 2 (Perspective: internal, external) repeated-measures design to measure the tactile or visual descriptions' effect on the verification of event pictures. Participants read a scenario and then verified whether or not the picture showed the scenario's transitive action. Instructions told participants to consider the action, while ignoring the picture's perspective and the pictured object's visual or tactile property. For example, participants should only press 'yes' when the action appeared to be in progress, even if the perspective of the picture does not match the narrative suggested perspective. Excluding null pictures, all pictures did match the described property. However, the researcher instructed the participants to not base their decision on whether or not the pictured object matched the scenario's object-property description, because some people may conceive certain properties differently than the pictures (e.g. people may consider the pictured *brown* package to actually be tan; glare on the shiny *black* stapler makes it look partially white).

Before seeing the main stimuli, each participant practiced the task. The practice block consisted of 14 trials. Three of the five practice scenarios were reused within the practice block, but each instance used different pronoun, validity, and perspective conditions. For example, the trials focused around *peeling an orange*, but each used a different pronoun. Each trial used abbreviated, two-sentence scenarios. The practice block served to confirm that participants understood the instructions, specifically to verify the transitive action, as compared to the perspective of the pictures or the tactile or visual property.

Practice scenarios were presented in a fixed order. The first six trials were all valid. The next six were invalid and the final two were null. Across all 14 trials, the three possible pronouns and two perspectives were rotated through the scenarios. After every two trials, the assigned property switched from visual to tactile or vice versa, such that half of the trials used visual properties and the other half used tactile properties.

Each scenario sentence was displayed individually for 3000 msec. The final discourse sentence was followed by a 500 msec fixation cross, centered on the screen. After the fixation cross, the computer displayed one of the four scenario–matched images (or one of the null images), centered, also centered on the screen, for a maximum of five seconds, or until the participant responded, whichever came first. Participants responded yes or no to each image via the keyboard (yes via left index finger, no via right index finger).

Feedback was provided after each practice trial. Correct responses led to a 750 msec display of '*Correct!*'. Incorrect responses led to a re-presentation and brief reminder of the instructions, available until the participant pressed a button on the keyboard. Then the trial would repeat. This feedback could repeat indefinitely for a given trial, such that the practice block did not end until the participant achieved 100% accuracy (all 14 images correctly verified).

The experimental block differed in three ways from the practice block. First, twenty-four, four-sentence scenarios were used. Second, the trials did not give feedback. Third, the software (Superlab 4.0) randomized the scenario order within each participant.

Each participant saw all 24 experimental scenarios. Given the 3 (Pronoun: *I*, *You*, *He*) x 2 (Perspective: internal, external) x 2 (Modality: visual, tactile) repeated measures design. Scenarios were rotated through the 12 conditions using a partial Latin square.

The null trials served to ensure that the participant was fully reading the scenarios and not merely relying on heuristics. For example, they may have been simply pressing yes in response to any picture showing an action. Alternatively, they could be relying on low-level perceptual features such as whether both hands were in contact with the object and tool, which topographically evoked a continuous form across the computer screen. Typically, invalid pictures showed the hands slightly distant from the object, thus not evoking a continuous form. Also within a tactile/visual half, participants read four scenarios containing each of the three possible pronouns. Six of the pictures in a half depicted actions from an external perspective, and the others were from an internal perspective. Across participants, scenarios were rotated through the three pronouns, and images were rotated through the three validity conditions (valid, invalid, null) in a partial Latin square.

Results

Five exclusion criteria were applied to data prior to formal analyses. First, the first seven participants of the study were excluded due to inadequate instructions, as evidenced by low overall task accuracy rates (75%). Second, three participants were excluded due to their prior participation in a related study (specifically Brunye et al, 2009). Third, four participants were removed due to poor performance in the practice session, as determined by accuracy rates equal to or lower than 75%. Fourth, a total of two participants were randomly removed to balance the Latin square design. Finally, we removed 30 response time outliers (Mean +/- 2.5 SD) on a per condition basis (constituting 3.5% of all trials). The analyses considered data from the remaining 78 participants (28 males; *M* age = 19.3 years).

Analyses

We conducted two omnibus repeated-measures ANOVAs, one for accuracy and one for response time, in a 3 (Pronoun: *I*, *You*, *He*) x 2 (Modality: tactile, visual) x 2 (Perspective: internal, external) design. In a follow-up set of analyses, we also included participant gender (male, female) as a between-participants factor. An alpha level of .05 was used for ANOVA effects. Follow-up comparisons were done using paired t-tests.

Accuracy

An ANOVA on accuracy data revealed main effects of Pronoun (I, You, He), $F(2, 154) = 13.40$, $p < .01$, Modality, $F(1, 77) = 6.15$, $p < .05$, and Perspective, $F(1, 77) = 14.84$, $p < .01$. These effects were qualified by two interactions. First, there was an interaction between Pronoun and Modality, $F(2, 154) = 3.35$, $p < .05$, as depicted in Figure 2. A follow-up paired t-test demonstrated that within the You condition, the Visual condition had higher accuracy relative to the Tactile condition, $t(77) = 2.25$, $p < .05$. Second, there was an interaction between Pronoun and Perspective, $F(2, 154) = 4.28$, $p < .05$, as depicted in Figure 3. A follow-up paired t-test demonstrated that within the You condition, the External condition had higher accuracy relative to the Internal condition, $t(77) = 3.04$, $p < .01$.

Response Time

An ANOVA on response time data revealed a main effect of Pronoun, $F(2, 64) = 3.25$, $p < .05$, and a main effect of Perspective, $F(1, 32) = 9.65$, $p < .01$. Follow-up comparisons within the Pronoun variable revealed faster response times in the He condition (*M* = 964.15, *SE* = 35.92) relative to the You condition (*M* = 1027.6, *SE* = 46.46). In the Perspective variable, there were faster response times in the External condition (*M* = 830.92, *SE* = 27.24) relative to the Internal condition(*M* = 972.56, *SE* = 53.87). All other results, such as comparisons between factors, were nonsignificant.

Gender

Follow-up ANOVAs including gender as a between-participants factor revealed that within response time, the two main effects (Pronoun, Perspective) interacted with participant gender. First, we found a marginal Pronoun by Gender interaction, $F(2, 62) = 2.48$, $p < .10$, suggesting that the main effect of pronoun was only found in females, not males (see Table 2). Second, we found a Perspective by Gender interaction, $F(1, 31) = 6.69$, $p < .05$, again suggesting that the main effect of Perspective was only found in females, not males (see Table 2).

Discussion

After reading second person narratives, in which the pronoun disambiguates the agent from the reader, people judge internal pictures faster than external pictures (Brunye et al., 2009). The exact opposite behavior occurs when reading first or third person narratives. One explanation for this behavior is that people simulate the narratives perceptually from a specific perspective, depending on the pronoun. When they read *You* based narratives, they simulate it from the actor's perspective, and because this matches the perspective of internal pictures, they judge those pictures more quickly than external pictures. Likewise, reading *I* and *He* based narratives induces observer-perspective simulations which facilitate judging external pictures relative to internal pictures.

This simulation explanation is founded in the theory of grounded cognition which proposes people represent concepts using the same neural networks as the networks used to perceive and act out those concepts (Baralou, 1999). The modal (i.e. perceptual) symbols contain perceptual information about their referent, allowing the mind to directly derive affordances from the symbols or concepts. Based on the indexical hypothesis, people should comprehend the aforementioned narratives by mapping words to their exemplifying perceptual symbols (Glenberg & Kaschak, 2002). Then the reader should simulate how the concepts interact, as guided by the sentence syntax or construction. Various studies support the existence of perceptual symbols and their use in language comprehension (Borghi et al., 2004; Gentilucci, Benuzzi, Bertolani, Dapratii, & Gangitano, 2000; Glenberg & Kaschak, 2002; Klatzky, Lederman, & Matula, 1993; Tucker & Ellis, 2004; Zwaan & Taylor, 2006). These likewise cast doubt on traditional language comprehension theories that largely utilize amodal symbols. In Brunye et al.'s (2009) study, the narrative pronoun appeared to be the primary determinant of the simulation's perspective. Because reading tactile descriptions should also engage first-person sensorimotor simulations, the present research hypothesized that participants would judge internal pictures most accurately and quickly after reading second-person narratives (i.e. when pronoun was *You*) and tactile descriptions (regardless of pronoun). Contrary to these hypotheses, neither of the participants' performance metrics varied as a function of Pronoun, Modality, and Perspective combined, but the results did demonstrate a few main effects and two-way interactions, as described below.

Main Effects and Interactions

Participants less accurately judged pictures after reading second-person narratives (i.e., *You are…*) than first person and third person narratives (i.e., *I am… He is…*). The main effect of

Pronoun was qualified by its separate interactions with Modality and Perspective. In terms of Modality, the tactile condition showed lower accuracy than the visual condition, but only within the *You* condition. That is, when participants were directly addressed as the subject of the narrative and received a tactile description, they also showed reduced accuracy when making picture verifications. In terms of Perspective, the internal condition showed lower accuracy than the external condition, and this also only occurred within the *You* condition. When participants were directly addressed with the pronoun *You,* they appeared to perform best when given visual information and an external image perspective. Perhaps, they assumed the agent's role and simulated the narrative with visual specifics, but the external image disambiguated them from the true narrative agent, so they returned their focus to the action, rather than the pictured object's visual properties. However, such an explanation is speculative.

Response times generally mirrored accuracy data, with slower picture verification following second person narratives than third person narratives; interestingly, this effect was only found in female but not male participants. Slower picture verification was also found when participants confirmed Internal versus External images; similar to pronoun data, a marginal interaction suggests that this effect was only found in female but not male participants. The present research's goal did not center on gender differences, but perhaps because the event images used male hands, female participants had to overcome the visual difference between their simulated arms and the event image arms, as suggested by longer processing time.

Hypothesis's Crux

Reading narratives written with specific pronouns and modal-specific information before judging internal or external pictures did not interact to affect accuracy or response time. The results do not support the hypothesis, and likewise may not support perceptual symbol theories.

If the mind represented words through modal symbols, these symbols should interact to modulate simulation perspectives, which should differentially facilitate or interfere with judging pictures of similar or conflicting perspectives, respectively. Reading tactile information does not appear to modulate the perspective of narrative simulations by directly or indirectly inducing tactile simulations. Tactile simulations are inherently egocentric, and therefore might specify an egocentric visual simulation. The idea that tactile simulations would specify visual simulations is apparently false. Alternatively, any induced simulations may terminate prior to the event image presentation, and, thus have a limited influence on the task. Lastly, reading tactile information might neither directly nor indirectly induce tactile simulations, at least in this particular methodology. Three different lines of logic justify the proposition that tactile simulations would specify visual simulations.

First, reading about action might induce tactile simulations especially when the narrative explicitly specifies a direct object's tactile property. Acquiring tactile information requires direct interaction with world. The interaction can be simple physical contact (i.e. determining an object's temperature), but is most likely dynamic such as applying pressure to the object's surface (i.e. to determine plasticity) or moving the hand across the object's surface (i.e. to determine surface texture).

Second, reading tactile information may engage tactile simulations directly. The indexical hypothesis proposes that people learn words through operant conditioning, so understanding the word *soft* developed from associating perceiving softness with the orthography and phonology of *soft* (Glenberg & Kaschak, 2002). For example, touching a fake stuffed rabbit while reading about the softness of rabbit fur.

Reading tactile information might induce tactile simulations in a third manner. People can perceive an object in one modality and use this modal-specific object representation to recognize the object in a different modality (Bushnell & Baxt, 1999). This cross-modal recognition suggests modal representations can inform representations in different modalities. When readers simulate the narrative visually, the visual simulation may therefore automatically engage an appropriate tactile simulation. Furthermore, visually determined affordances can directly influence action (Tucker & Ellis, 2001, 2004). As previously discussed sensorimotor representations may engage tactile simulations, because of their interdependence. So because of cross-modal recognition and how affordances can influence action, reading tactile information may indirectly induce tactile simulations.

Perceptual Symbols Persist

Three aspects of grounded cognition may explain why reading tactile information did not induce tactile simulations or why a tactile simulation may not have modulated the visual simulation's perspective. First, perceptual symbol theory is a featural representation theory. The meaning of a given word or concept arises from a collection of individual, reusable components (Vigliocco & Vinson, 2007). Perceptual symbols are transduced from neural subsets of perception, isolated via selective attention. Perceptual symbols' dynamic nature and the modal representation's componential nature permit the same perceptual symbols to be used for different concepts. For example, the mind might represent use the same *softness* perceptual symbols for both a pillow and a down comforter. A given word, such as *tomato*, is represented by multiple components (i.e. features) from an array of modalities. Therefore, a given word can be partially represented. For example, only representing how a tomato looks, but not how it feels, or vice versa. If word meanings can be partially simulated, then if reading tactile information does directly or indirectly induce tactile simulations, then the mind does not necessarily also induce other components of the word meaning, such as perspective specific visual simulations.

Given the word representations' componential nature in perceptual symbol theory, tactile simulation would force a visual simulation only under specific circumstances. If the tactile and visual properties were mutually inclusive, then simulations of both modalities might arise. Unfortunately, unlike orientation and shape, or being trilateral and being triangular, the author cannot imagine a tactile and a visual property, which necessitates the other. Additionally, the simulations may rely on degrees of attention, intention, and necessity. Perceptual symbols form from selectively attending to a perceptual state component. If one rarely attends to thei perceptual state's tactile components, then their tactile symbols may be few or difficult to engage. Even if one does have many, strong tactile symbols, perhaps they must intend to use the symbols to inform visual simulations, as in cross-modal recognition tasks (Bushnell & Baxt, 1999). The person may instantiate a need for the tactile representation. Similarly, object affordances may certainly partially depend on the object's tactile properties, but people most likely do not need to consciously acknowledge the tactile properties to effectively utilize an affordance. The tactile property of an object may be assumed. For example, while a well-designed laptop may have hard keys, probably very few laptops have soft, mushy keys, that truly limit their affordances. If people rarely need to consciously know an object's tactile affordances then they may also rarely associate tactile simulations with visual simulations.

If reading tactile information induces tactile simulations, the simulations may be too weak or subtle to modulate visual perspective simulations. The tactile simulations may also not transfer to this study's visual task. Having few or rarely activated tactile symbols could limit the tactile simulations' strength. Glenberg and Kaschak (2003) only demonstrated ACE for gross physical responses. When participants' hands were already in the distal or proximal positions, reading sentences, which implied one direction, did not interfere with pressing buttons in conflicting positions (i.e. reading *Close the drawer*, which implies a moving distally, but confirming the sentence by using your hand already proximal hand to press the proximal button). Similarly, in other experiments where reading about actions appeared to use the same representation system as executing those actions, the responses were gross movements (Borghi et al., 2004; Gentilucci et al., 2000; Glover et al., 2004). People most likely only attend to tactile properties during fine motor movements. If action representations must be gross to conflict with semantic representations, then perhaps the tactile simulations are too subtle to interact with motor or visual simulations.

Although the results may appear to provide contradicting evidence to perceptual symbol theories, the limitations described above still permit reading to engage perceptual simulations. The tactile simulations may have been unnecessary, unconnected, or too weak to modulate the visual simulation. In fact, anecdotal evidence supports perceptual symbol theory and provides an additional framework to possibly explain the results. Anecdotal evidence suggests specific peceptual features strongly influenced participant responses. One participant reported that she incorrectly responded 'no' to the *soap dispenser* item, because the image did not match her internal representation of a canonical soap dispenser. Similarly another participant incorrectly responded 'no' to the package item, because the package, a brown paper wrapped box, did not look *flexible*, contrary to the narrative's descriptive sentence. Participants, against the researchers' instructions, may have partially performed the task based on the properties provided in the fourth sentence. This suggests they automatically simulated those properties and used them as criteria. These two propositions imply modifications in participant simulations and decision processes that might have effected the present research's results.

Readers Focused on the Self

Tactile and visual information appeared to induce richer simulations, albeit not necessarily perspective specific simulations. Participants may have simulated the objects with the described properties, and then attempted to visually confirm that the pictured objects instantiated the properties. With these two behaviors in mind, a general pattern emerges from the significant main effects and two-way interactions.

People appear to more critically analyze situations that are self-relevant. When participants read scenarios and verified pictures referred to themselves or their actions, they appeared to more strictly judge the pictures. This led to reduced accuracy rates. All three experimental factors could vary in terms of self-relevance. The narrative pronoun was *I*, *You*, or *He*. Brunye et al. (2009) demonstrated that after reading a brief narrative written in the third-person (i.e. *He*), people appeared to simulate the narrative from the perspective of an observer, watching *He*. In contrast, they assumed the protagonist's or agent's perspective if the narrative was written in the first or second person (i.e. *I* or *You*, respectively); they imagined themselves as the agent. However, if the narrative disambiguated the agent from the reader, only a second person narrative induced the effect. Clearly, being directly addressed is more self-relevant and induces a different behavior. Overall, *You* appears to be the most self-relevant, then *I*, then *He*.

The Modal factor had two levels, visual and tactile. Some visual properties, such as shape, imply affordances. Therefore an object's visual properties had egocentric implications to the reader, if the reader had assumed the protagonist's role (or at least perspective). An object's tactile properties also imply its affordances. Therefore, an object's visual properties also had egocentric implications to the reader, if the reader had assumed the protagonist's role. However, not all visual and tactile properties significantly determine an object's affordances. For example, a laptop's affordances do not vary as a function of its color (unless different materials account for the different colors). Similarly, people most likely hold a candle the same way, whether it is warm or cool (a hot candle is an exception). Since most of the visual properties used in the study did not specify object shape, the author generalizes that more of the tactile properties had egocentric implications than the visual properties. Furthermore, visual information can be acquired without directly contacting the object, while tactile information can only be directly acquired through physical contact. So reading tactile information is more self-relevant than reading visual properties.

Lastly, the picture perspective could vary in terms of self-relevance. An external picture disambiguates the agent. By conveying the event (valid or invalid) from an observer's perspective, it suggests to the reader that someone else is the agent, even if the narrative directly addressed the reader with the pronoun *You*. Conversely, an internal picture depicts the event from the agent's perspective and so readers may be more likely to assume or continue to assume the agent's role (or at least the agent's perspective). Internal pictures are therefore more self-relevant than internal pictures to the participant.

Differences between the Present Research and Brunye et al.'s 2009 study

Scenario relevance to the self did not appear to affect performance in Brunye et al.'s 2009 study, possibly because adding the modal specific information altered the task and might have changed participant behavior in several ways.

As anecdotal evidence suggest, adding modal-specific information altered their simulations and their judgment criteria. Participants incorporated the verbal property descriptions into their simulations. This made the simulations richer, or at least more specific. This could have led to greater, but more nuanced, disparity between their simulations and their event images' mental representations. Greater disparity between simulations and valid event images (pictures which did depict the agent executing the action) could have misled participants to incorrectly respond 'no'. This would be true even if small details accounted for the greater disparity, especially if the participant was attending to those small details. As suggested by anecdotal evidence, the mere additional property description led participants to use the object property descriptions as criteria to judge the event images, even though the researcher instructed them only use the event action as a criterion. People could not use property descriptions as accurate criteria, so this also could have impaired performance, again, especially if they were attending to the specified properties. Participants read the descriptive sentence last. This could have diverted their attention away from the action and towards the modal-specific property. Not only is this incongruent with the instructed task, but it also encourages participants to develop richer simulations and focus on the object property. These effects could exaggerate the following two behaviors: incorrectly focusing on small details and using the property descriptions as criteria.

The additional sentence also drove a spatiotemporal gap between the narrative's last use of the pronoun and judging the picture. This could have reduced pronoun's self-relevance effect, but the gap was not a void. The descriptive sentence filled the spatiotemporal gap. And by enriching the simulation, it may have also emphasized the pronoun's self-relevance effect. For example, tactile properties aided the pronoun *You*'s self-relevance. Also, the descriptive sentence induced the previously described effects. A simple alteration could mitigate some of these problems. The experiment should have added the modal-specific property as an adjective to the direct object in the action sentence, rather than as a full additional sentence. For example, the scenario could combine the action and descriptive sentences *Right now, you are slicing the tomato*/*The tomato is soft* into *Right now, you are slicing the soft tomato*. This could maintain focus on the event action. Furthermore, presumably any reading induced simulation eventually decays. The action simulation might have terminated before the participant judged the event image, leaving the participant to use the property-simulation as a criterion.

Self-relevance Elevates Judgment Criteria

The following attempts to explain the present results using the concept of self-relevance and the richer simulations.

Participants less accurately and less quickly judged pictures after reading second-person narratives (i.e., *You are*…) than first person and third person narratives (i.e., *I am*…, *He is*…). Within the *You* condition, they responded less accurately after reading tactile descriptions than visual descriptions. Here, the two most self-relevant levels of the Pronoun and Modality factors interact to significantly manipulate participants' judgment criteria. First, reading the second-person narrative causes the participants to simulate the narrative from the agent's perspective, as if they were the agent. Internal perspective simulations might be richer or more nuanced then external perspective simulations. People might pay greater attention to the own actions' perceptual details than the actions of others, because they may need those perceptual details to execute the actions. Even if they have seen others execute the scenario actions more than they have executed the actions themselves, because the actions are mundane, the participants still probably did not significantly attend to the actions perceptual details. The richer simulations are further specified and focused on perceptual details, because the participants read descriptive sentences. The tactile properties, which have greater affordance implications and can only be acquired through direct physical contact, are more self-relevant than the visual properties. Because these factors—Pronoun and Modality – both imply how the participant is fictionally behaving, the participants over-raised their judgment criteria in the *You*-tactile condition and judged pictures less accurately. This is evidenced by the reduced accuracy and the anecdotes revealing participants simulated the described object properties and sought to confirm the pictured objects instantiated those properties. The lack of this interaction in response time suggests that participants automatically raised their judgment criteria rather than altering their decision making process, but is more likely due to only including correct trial response times in the analysis.

An alternative reason reading tactile information generally impaired performance is that switching attention across modalities costs mental effort. The mind might focus on a particular word or concept component at a given moment. Switching focus between components of different modalities appears to induce a switching cost, both when actually perceiving different modal components and when reading about different modal components (Pecher, Zeelenberg, & Barsalou, 2003; Spence, Nicholls, & Driver, 2000). Tactile conditions may have forced the reader to switch focus across modalities twice. Participants first automatically simulated the narrative visually. Then reading the tactile information switched their attention to the simulated tactile modality. Then seeing and evaluating the picture switched their attention back to the visual modality (they needed to compare their simulated and perceived visual representations of the action). The multiple switches could have, in conjunction with the self-relevance of the *You* pronoun, impaired participants' judgment.

The Pronoun factor similarly interacted with the Perspective factor. Participants responded less accurately in internal condition than in the external condition, and this also only occurred within the *You* condition. Presumably, they assume the perspective of the agent, simulate the narrative more richly, focus on the object's properties, and attempt to confirm the properties' instantiation. When they see the internal picture, they continue to assume the agent's role and the elevated judgment criteria impairs their performance. Conversely, seeing the external perspective picture disambiguates the agent and, perhaps, allows the participant to focus on the event image's action. External image's facilitating main effect on both accuracy response time support this proposition. However, because participants changed their response criteria and not their decisions' deliberateness, Pronoun and Perspective did not interact in response time.

Pronoun induced a main effect on both accuracy and response time. Reading second-person narratives impaired performance. While Pronoun's main effect in accuracy is qualified by its independent two-way interactions with Modality and Perspective, its main effect in response time is not qualified by other interactions. This similarly indicates that the only significant two-way interactions involved Pronoun. The narratives' suggested perspective therefore appears to be the most dominant factor in determining self-relevance. In Brunye et al.'s 2009 study, it forced people to assume the agent's perspective, even when the agent's age and occupation distinctly did not match the reader's age and occupation. Pronoun's dominance underscores the subtlety of the other factors. As previously discussed, Modality's potential is limited by tactile simulation's subtlety or weakness.

After reading the object descriptions, participants may look for the described properties in the event images. However, people cannot directly perceive tactile properties through vision. They must infer these properties visually. Inferring tactile properties visually should be more difficult than inferring visual properties visually. Furthermore, inferring tactile properties may be more difficult when judging an agent-object interaction from an onlooker's perspective. People should not strongly associate an object's tactile properties and visually hints to those tactile properties based on other's peoples' actions. They cannot simultaneously experience the tactile properties and agent-induced visual hints, because they are not the agent. Neither of the participants' performance metrics varied as a function of Modality and Perspective factors combined. This suggests that although reading tactile information generally inhibited performance, but judging an external event facilitated task performance, these main effects partially negated each other.

When participants read a second person narrative, they simulated it from the agent's perspective. They would then focus on the object property and attempted to confirm the property's instantiation in the event image. The tactile properties made the scenario more self-relevant and thus raise judgment criteria and thus impair judgment. In the internal condition, the self-relevance increased, but participants could more easily infer the tactile property visually. In the external condition, the picture's perspective made it more difficult to infer the tactile property, but it also disambiguated the agent, and reduced the scenario's self relevance. The negation of Modality's and Perspective's main effects explains why in the three-way factor analysis, the most self-relevant levels of the three factors (Pronoun's *You* condition, Modality's tactile condition, and Perspective's internal condition) did not interact to significantly impair performance in either metric.

Future Directions

Future studies should seek to clarify the assumptions made in the present research, particularly whether or not reading tactile information induces tactile simulations. Perhaps participants could read sentences which implied warm or cold temperatures and have to respond through warm or cold joysticks or other input devices. The primarily problem in this paradigm is effectively manipulating input device temperature and keeping the participant naïve to the study's purpose. In the context of the present paradigm, two changes could clarify its effectiveness. First, as mentioned earlier, the object property should be incorporated into the action sentence (i.e. *Right now, you are slicing the soft tomato*). This keeps focus on the scenario action and reduces the spatiotemporal distance between reading the pronoun and judging the event images. Second, participants should take a pre-announced memory test after the main experimental block. This would encourage the participants to read the entire scenarios and provide an opportunity to measure how the factors affect memory.

The present results are most readily applied to the design of technical documentation or user manuals. Given that such documents most likely provide instruction to the user using imperative sentence construction (which implies an understood pronoun *You*), all associated pictures should represent the action from the agent's perspective. As Brunye et al.'s 2009 study demonstrated, people confirm actions in event images more quickly when the perspectives of their simulations and the event images are congruent. If the document must describe the visual or tactile properties of the product, the present research prescribes that the pictures should be abstract. For example, simple line drawings should be chosen over in situ photographs. This prevents the reader from looking for the exact described object properties, because he should realize the photograph is not realistic enough to demonstrate those unnecessary subtle details. Using abstract images is already beneficial to technical documents, because it most likely reduces document printing complexity and allows cosmetic variations to not force technical document updates.

Conclusion

Reading modal specific information in a narrative does not modulate the simulations' perspective. However, the results and anecdotal evidence suggest that participants automatically simulate the modal specific information, supporting perceptual symbol theory. Directly addressing the reader and pushing their attention towards an objects modal properties, caused participants to simulate the narratives activate the properties' perceptual symbols and create richer simulations, but it also interfered with tactile simulations potential to modulate simulation perspective.

The automatic property-verification and self-relevance premises largely explain the present research's results, but remain speculations. Participants automatically simulated the described property and tried to confirm that the pictured object instantiated the property. This altered their response criteria. Furthermore the different factors related the scenarios to the reader in varying degrees. Participants appeared to judge pictures more critically if they saw more self-relevant the scenarios and pictures. This led to impaired performance.

Three features of perceptual symbol theory already limited tactile simulations potential to modulate simulation perspective. The componential nature of semantic representation suggests simulating an object's tactile property could be independent to simulating the object's visual properties. People rarely attend to tactile properties, so they might simulate tactile properties weakly. Furthermore, tactile simulations may not interact with action representation (in reference to motor resonance), because its affordances implications are too subtle. An object's tactile properties partially define its affordances, but most likely only fine motor control affordances. For example, the same gross hand posture could hold a soft and hard tomato; the motor control would only vary by subtle degrees of pressure. The ACE only occurs for gross motor movements. Therefore even if reading did activate tactile simulations, which fits within perceptual symbol theory, they may not modulate visual simulation perspectives.

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Table 1

Experimental Block Adjectives and Verbs by Object

Object	Visual	Tactile	Verb
cream cheese	white	creamy	spreading
tomato	red	soft	slicing
champagne	amber	wet	uncorking
brownie	dark	crusty	halving
candle	purple	warm	lighting
can	silver	stiff	opening
coat	gray	itchy	zipping
coconut	hazel	hairy	cracking
soap dispenser	orange	slimy	refilling
cucumber	long	bumpy	peeling
egg	brown	fragile	breaking
paper	rectangular	thick	stapling
syringe	clear	slippery	filling
pants	navy	silky	ironing
laptop	indigo	smooth	typing
blocks	painted	firm	stacking
melon	pale	moist	coring
trash bag	black	greasy	tying
package	opaque	flexible	taping
bill	flat	flimsy	tearing
steak	pink	tender	cutting
phone	blue	hard	dialing
cactus	speckled	sharp	watering
toothpaste	green	sticky	dispensing

Table 2

Response Time(msec) as a function of Gender and Pronoun

	Gender			
	Male		Female	
Condition	Mean	SE	Mean	SE
Pronoun				
I	832.3	56.3	902.9	42.6
You	806.8	82.6	1042.7	64.4
He	795.7	59.8	914.1	45.2
Perspective				
Internal	810.5	83.1	1065.1	62.8
External	812.7	45.7	841.4	34.6

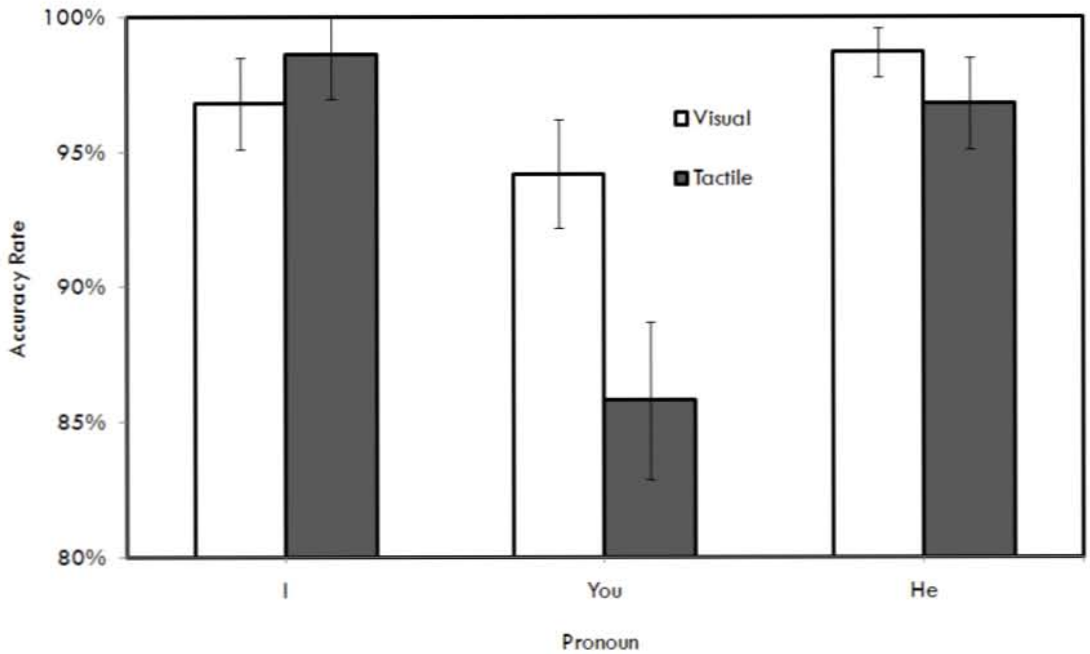
Figure Caption

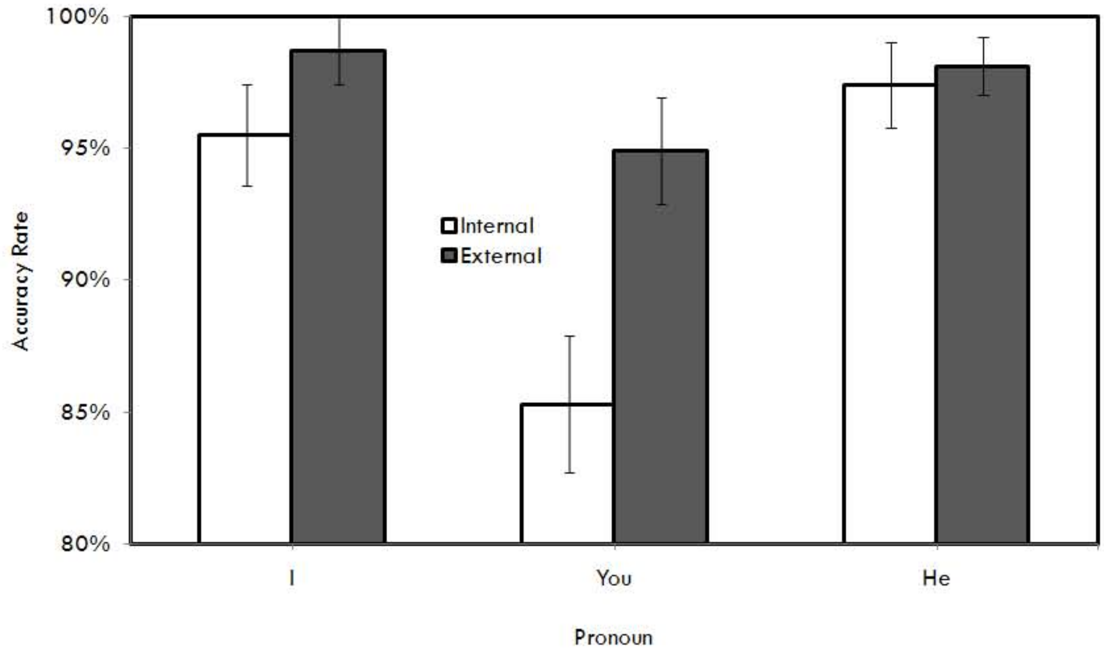
Figure 1. Event images either validly matched the preceding discourse or did not. They also either depicted an event from the agent's internal perspective or an external, onlooker's perspective.

Figure 2. Mean accuracy rate (±*SE*) as a function of Pronoun and Modality. Ss performed significantly worse in You-tactile condition.

Figure 3. Mean accuracy rate (±*SE*) as a function of Pronoun and Perspective. Ss performed significantly worse in You-Internal condition.

	Perspective	
Validity	Internal	External
Valid		
Invalid		


100%
95%
90%
85%
80%
Accuracy Rate
Visual
Tactile
I
You
He
Pronoun


100%
95%
90%
85%
80%
Accuracy Rate
Internal
External
I
You
He
Pronoun