

IF A TREE FALLS IN THE FOREST, WHAT DIRECTION DOES IT FALL:

WRITING DIRECTION'S ROLE IN MENTAL SIMULATION

By

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If a Tree Falls in the Forest, What Direction Does It Fall:  
Writing Direction's Role in Mental Simulation

Abstract

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Mental simulation plays a key role in language comprehension. The present study examines the potential for direction as an element of mental simulation. Research on writing direction indicates that people prefer information that is congruent with their writing direction; the present study examines whether this preference extends to mental simulations. In an experiment, participants listened to sentences that implied movement (e.g. "The man runs.") and were then presented with a black silhouetted image that was either facing left or right. They judged whether the image matched the information in the sentence. Responses were faster when images were facing right than left, congruent with the participants' writing direction. Direction had no effect on accuracy. These results support the hypothesis that direction is activated during language comprehension and biased by writing direction. Implications of these results are discussed in regards to mental simulation, perceptual symbols systems, embodiment, and blending.

*Keywords:* mental simulation, writing direction, embodiment, mental representation, perceptual symbol systems, language comprehension

## Introduction

Over the past two decades, there has been a shift in how mental representation is conceptualized, moving from amodal symbols with independent perceptual and conceptual systems to modal, analog symbols powered by a common system including both perception and conception. These changes have led to a renewed focus on the mechanisms of language comprehension. Theories within grounded cognition emphasize the relationships between experience and cognition. Barsalou (1999) argued that experiences are broken up into perceptual symbols (or elements) based on attention during the experience and these elements are reactivated during language comprehension via mental simulation. - Theories of embodiment argue that our bodies play an intricate role in how we experience the world. A number of studies have addressed the issue of representation and comprehension using reaction time tasks to measure whether implied information in a sentence is included during mental simulation. The results have been taken as outright evidence of a modal, analog mental representation system, but these studies have stopped short of testing a truly modal model.

These studies, however, are weakened by a misunderstanding of what amodal models are (and can be), as well as by failure to incorporate implied embodiment and non-direct experience recall network elements. Amodal models are usually described as having only a single representation of a given entity - no matter the variation in the entity's forms and circumstances. Though the studies referenced above claim to give evidence for analog representations, in their current state they, at best, only challenge the classic single-representation amodal model.

Amodal models are often explained using a misleading computer analogy, wherein they function like input and output does for a computer program. A computer image search, for example, is amodal. Two distinct search terms will summon different results, but two separate computers will still return the same results for the same term. Consider the following:

- 1) *The eagle is in the sky.*
- 2) *The eagle is in the nest.*

For current amodal models, these two sentences would be represented as [IN[EAGLE,SKY]] and [IN[EAGLE,NEST]], which would call up the single eagle representation and place it in the sky or nest, respectively. This presupposes that mental representations are directly tied to objects we can describe in a single word, so that there cannot be an amodal model for SKY EAGLE and one for NEST EAGLE. By this reasoning, these meanings would be built from individual representations for EAGLE, SKY, and NEST. However, research on analog representation has not yet given adequate consideration to the possibility of complex amodal representations such as SKY EAGLE, and so it is too early to fully reject amodal models of representation.

Studies of mental representation have to date largely focused on amodal representations; in order to truly test for analog mental representations, the study design would have to balloon to hundreds of stimuli for each object, and additionally get extensive backgrounds on each individual participant. This is necessary to see if participants' reaction times matched up with their experiences and resulted in their



predicted prototype representation having the fastest reaction time. This would be an impossible study to conduct, but there is another solution.

The present study addresses the problems laid out above by using direction as the implied embodied element to be tested. Research has shown that writing direction leads to an embodied directional bias which impacts a number of behaviors and preferences, such as scanning (Abed, 1991; Nachson, 1985; Padakannaya, Devi, Zaveria, Chengappa, & Vaid, 2002). The presence of a directional bias matching writing direction during mental simulation of sentences with implied horizontal direction would provide evidence that individual embodied experiences affect mental simulation. This simulation occurs independent of the direct experience elements being recalled, resulting in truly modal, analog representations.

The difference being that people could feasibly have amodal SKY EAGLE and NEST EAGLE representations based on an amodal categorization system that differentiated between the two, but showing a clear preference for SKY EAGLE LEFT-FACING or SKY-EAGLE RIGHT-FACING based on writing direction would be a clear indication of a perceptual symbol element from a different experience affecting the mental simulation of a separate experience.

## **Mental Representation**

### **Theory**

Although extant research has yet to definitively prove the existence of modal, analog representation during mental simulation, Barsalou's (1999) perceptual symbol systems provide a strong theoretical groundwork from which to build. Under the larger framework of embodied cognition, Barsalou has laid out a theory for mental

representation that finds support from other theories such as blending and images schemas in addition to general embodiment. Mental Representation refers to the process(es) by which perceptions becomes conceptions, which in its simplest form consists of an Experience → Input → Output pattern (Barsalou, 1999). There are two important elements of the output step: mental simulation and mental imagery. Mental simulation is the unconscious process that occurs when comprehending or conceiving of information. Mental imagery refers to the conscious process that occurs after mental simulation and allows an idea to be considered. Not all mental simulations lead to mental imagery, but all mental imagery is preceded by mental simulation.

Perceptual symbol systems propose three major changes to previous mental representation theories. Foremost, there are not separate perceptual and conceptual systems, but instead what is perceived and consequently encoded is directly accessed during conception and/or comprehension. Additionally, the other two changes are directly related to this major change: that experience is encoded as perceptual symbols which are modal analogs of their referents, and that these symbols are reactivated during mental simulation.

While Barsalou (1999) addresses all types of output when laying out his theory, research has focused predominantly on language comprehension. For language comprehension, perceptual symbol systems provide a testable theory. During language comprehension, each word is attended to and comprehended in real time, allowing for conversations to proceed at the rates people are accustomed to. This comprehension relies on past experiences to accurately represent what a person is hearing or reading. The

patterns that were encoded during the initial experiences are reactivated in order to run a mental simulation allowing for comprehension to occur.

Mental imagery occurs once this information is brought into consciousness, which occurs when a response is required (Barsalou, 1999). The perceptual symbols refer to the encoded information. As we experience the world, only certain information is encoded based on what we are paying attention to; each symbol represents an element of the experience, so that the information can be reactivated together or separately and combined in novel ways. That is, the mind can combine these elements to construct new concepts that have not been directly experienced. It is important to note that the analogs that are encoded are not vibrant high definition recordings of the experienced elements; rather, they reflect the schematic nature of concepts, calling up only those elements which set the generic frame for a scene.

The simplicity of the generic frame is what makes properly measuring perceptual symbol systems, so difficult and that current studies have not yet fully been able to measure. This is not to say that these studies should be ignored in any capacity, only that there is another step to be taken. In order to lay the groundwork for the present study, is important to lay out what the current research on perceptual symbol systems has found.

## **Research**

The research on perceptual symbol systems can be broken up into three categories: process, analogs, and simulation. Process studies provide evidence for the three steps of mental representation (i.e. Experience, Input, and Output) and outline how the studies in all three categories are not measuring different phenomena, as it seems they

claim to do. Analog studies illustrate the level of detail that is present during simulations. Finally, simulation studies measure how action is represented during simulation.

The analog and simulation studies form the backbone for the current research; of the studies discussed, many of the most influential will be reaction time studies. Reaction time studies are necessary in order to ensure that simulations - and not mental imagery - are being measured. Faster reaction times indicate that the information being responded to matches the simulation that occurs prior to the experimental stimuli being presented. Previous studies have found that reaction time is facilitated when the stimuli matches the participant's expectation (Zwaan, Madden, Yaxley, & Aveyard, 2004; Zwaan, Stanfield, & Yaxley, 2002; Stanfield & Zwaan, 2001; Zwaan & Pecher, 2012).

There exists a large body of literature in cognitive science supporting work done on simulation; among the most relevant lines of inquiry are those of embodied cognition, conceptual integration, and image schema. Embodied cognition is the theory that cognition is shaped by the body's experience of the world. For mental representation, this coheres with the perceptual symbol systems' concepts regarding experience and output. The way our bodies experience the world has a direct effect on how we are able to conceive of ideas in the future. If people's bodies create a filter for their experience, it follows that conceiving and comprehending would consider the body during mental simulation and not just during mental imagery.

In addition to embodiment, the theory of conceptual integration (blending) outlines how people are able to take concepts from different domains and cross-pollinate to create new ideas and understandings. If all experience were filtered into simple amodal categories before people could access elements for conception, it is hard to imagine how

new ideas or abstract thoughts could form. Underlying the ability to cross-pollinate ideas, image schemas are recurring patterns from cognitive processes that people can use to anchor complex thoughts and relate concepts to one another by either identifying a common structure in them or assigning one concept's structure to another (mapping).

Now, consider Bergen's (2012) Superswine and Pigasus – fictional pigs possessing the power of flight. This concept is something that people have never seen before, but have little to no trouble imagining. Experience leads to the knowledge that birds and Superman can fly, but pigs and humans cannot; however, we also recognize that birds and Superman differ in how they achieve flight. Based on these experiences we develop analog representations for people, pigs, birds, Superman, birds flying, and Superman flying. When conceiving of a Superswine/Pigasus, blending is used to take the part of either Superman or a bird that allows them to fly and combine it with a pig, which then imbues the pig with the power to fly.

One image schema is part-whole, a recurring pattern that illustrates how parts of a whole serve different functions. In this case, part-whole facilitates the understanding that outstretched wings or arms plus a cape allow birds and Superman to fly, respectively. In the present study, writing direction represents an embodied experience, that becomes tied to the source-path-goal image schema, resulting in a dominant horizontal directional bias during mental simulation. When no horizontal directional information is given for an action sentence, the dominant direction will usually be called into the blend in order to properly simulate and comprehend the information at hand.

## **Process**

The big changes in the mental simulation process proposed by Barsalou (1999) are: the idea of experiences being broken into symbols that are stored as schematic patterns; the notion that these symbols can be reactivated, leading to mental simulations; and the elimination of two separate systems for perception and conception, facilitating the development of analog representations. The simplicity of this system is necessary for the process to happen predominantly unconsciously. The goal of mental representation is to aid in comprehension, beginning with perception and leading to how we encode information.

The role of experience in mental representations is to provide opportunities for encoding that can be reactivated during simulation. People have limited attentional resources, so any experience is selectively attended to and only some of the information is encoded. The process or processes by which we choose this information is not very well understood. Presently, evidence has been found that environmental cues often guide our attention (Chokron & De Agostini, 1995). Generally, outside of cues designed to capture our attention, our attention is directed primarily based on our personal goals of understanding (Graesser, Singer, & Trabasso, 1994; Zwaan & Radvansky, 1998). On a case by case basis, these goals can probably be determined with some level of accuracy, but as a general idea, the concept is vague.

As demonstrated, evidence points to experience as a core component in mental representation. Much research points to repeated experience as the best factor at predicting encoding (Holt & Beilock, 2006; Zajonc, 1968; Moreland & Topolinski, 2010). The mere exposure effect finds that more exposure to stimuli leads to better perceptual fluency (Jacoby & Dallas, 1981). Our perceptual knowledge of an object

informs our conceptual knowledge of that object (Shepard & Metzler, 1971; Reed & Vinson, 1996; Vinson & Reed, 2002). Prior exposure to a stimulus leads to faster recognition and a lower N400 reaction upon re-exposure, evidence of a top-down process matching bottom-up processing, leading to less effortful perception. (Pecher, Van Dantzig, Zwaan, Zeelenberg, 2009; Coppens, Jootjes, & Zwaan, 2012). Experts show better comprehension of expertise-specific scenarios than non-experts, suggesting that experience is a crucial factor determining mental processing (Holt & Beilock, 2006).

Encoding during the mental representation process involves creating schematic representations of specific elements and mapping how those elements interact. During recall, associated elements are recalled along with the specific element being comprehended (Pecher et al., 1998). As such, the relationship between the shape of an object and the name of the object is encoded along with the name of the object and what the object can do (Reed & Vinson 1996; Vinson & Reed, 2002; Wassenberg & Zwaan, 2010). Likewise, the relationship between faces and their role as orienters of action are encoded, and abstract concepts are mapped onto physical concepts (Dahaene, Bossini, & Giraux, 1993; Boroditsky & Fuhrman, 2010; Boroditsky, Fuhrman, & McCormick, 2010; Santiago, Lupianez, Perez, & Funes, 2007; Tversky, Kugelmass, & Winter, 1991, Morikawa, McBeath, & Kaiser, 1992). These mappings, it seems, can include spatial location (Tversky et al., 1991; Reed & Vinson, 1996; Richardson, Spivey, Barsalou, & McRae, 2003).

During mental simulation, encoded information is recalled depending on comprehension (Engelen, Bouwmeester, de Bruin, & Zwaan, 2011; Dijkstra, Yaxley, Madden, & Zwaan, 2004; Madden & Zwaan 2006). Simulations represent information

based on our perceptual knowledge (Reed & Vinson 1996; Vinson & Reed, 2002); these simulations are fluid representations as opposed to a series of snapshot images of experience (Shepard & Metzler, 1971; Freyd & Finke, 1984). When shown a sentence, comprehension involves recalling sensorimotor experiences during simulation (Engelen et al., 2011; Dijkstra et al., 2004; Madden & Zwaan 2006). Additionally, when shown an image, linguistic representations are simulated (Wassenberg & Zwaan, 2010).

Simulations can recall single elements from previous experiences and combine these elements with different or new information (Chatterjee, Maher, & Heilman, 1995; Southwood & Basilico, 1999; Maass & Russo, 2003; Kaup, Yaxley, Madden, Zwaan, & Luedtke, 2007). Finally, recognition is faster when a simulation is similar to the information being comprehended (Roediger & McDermott, 1993; Schacter, 1995).

Research into the process of mental representation according to perceptual symbol systems has led to a deeper understanding of a number of steps in the process. Our attention to perceptual information is selective and determined by environmental cues and personal goals (Graesser, Singer, & Trabasso, 1994). Experience is necessary to create conceptual knowledge and more experience leads to more efficient conceptual knowledge. Encoding has been found from concrete to abstract information and the elements of experience are encoded both on their own and in association with other elements the experience. Information can be recalled in single elements, as part of an association, and in combination with elements from other experiences. Simulation can be effected by comprehension, age, and experience.

### **Analogs**



Due to our limited cognitive capacity, mental simulations are analog representations and not high-definition recordings. Much like the limited attentional capacity people have during experience, our limited cognitive capacity forces selective reactivation of specific elements. Research into what elements of mental simulations are recalled has identified a few details that are reliably represented: shape, orientation, color, and spatial location. There is a standard assumption that something explicitly referred to in a sentence will be simulated, so research has focused on the recall of information that is implied during comprehension and any potential mitigating factors in this recall. During language comprehension, traces from experience are reactivated via mental simulation. Implied information in a sentence is reactivated because of its association with the explicit information in the sentence. The sentence, *the eagle is in the sky*, is simulated with a flying eagle shape because experiences of an eagle in the sky are associated with the eagle flying (Zwaan et al., 2002). Shape, orientation, color, and spatial location have been found to be simulated when implied (Zwaan & Pecher, 2012; Zwaan et al., 2004). During action sentences, the presence of a direction for an action is implied even if the action itself is explicitly mentioned.

Simulation results in a faster reaction time to congruent images because top-down processing creates less reliance on bottom-up processing (Barsalou, 1999). Bottom-up processing becomes an act of confirmation instead of analysis and determination. Within the mental representation system, congruent simulation allows the recognition system to decide whether conception matches perception, where an incongruent system requires some degree of rejection of conception, follow-up by perception and processing of that perception for comprehension. This process is still incredibly fast and the reaction time

difference is small for congruent matching versus incongruent matching (object is depicted but not in implied shape, orientation, etc.) (Barsalou, 1999; Zwaan & Pecher, 2012). Bottom-up processing takes precedence over top-down processing, so when conception does not match perception it is quickly discarded (Barsalou, 1999).

During language comprehension, implicit information is activated for shape, orientation, color, and spatial location when the information is conveyed in writing and when it is conveyed orally (Zwaan & Pecher, 2012; Zwaan et al., 2004). Shape refers to the form objects generally take when in different situations, such as an eagle in the sky versus in the nest. Orientation is the alignment of an object either vertically or horizontally based on how it interacts with another object; for instance a nail going into a wall is horizontal, while a nail going into the floor is vertical. Color is implicitly represented in sentences like the steak is cooked (brown) versus the steak is raw (red), where the object's relationship to another element in the sentence implies that it will be a specific color. These results have been replicated using online studies (Zwaan & Pecher, 2012). Studies of shape simulation have found that similar shapes take longer to reject, and sometimes lead to incorrect responses, which fits with the representations being analogs rather than high definition representations (Zwaan & Yaxley, 2004). There is no difference in comprehension and the consequent simulation between elementary and middle school aged students (Engelen et al., 2011). However, in people over seventy years old, recognition overall is slower, and there is a larger reaction time gap between congruent and incongruent-matching recognition (Dijkstra, 2004). People with low reading comprehension show no difference in reaction time when there is no time delay between language comprehension and stimuli onset; however, they showed results

consistent with high comprehenders when a 750 millisecond delay was introduced (Madden & Zwaan, 2006). High language comprehenders showed a reaction time difference regardless of stimulus onset delay. When a forty-five minute onset delay was introduced, congruent matching images were still recognized faster, showing that visualization was not strategic, but natural during language comprehension (Pecher, et al., 2009).

Mental simulation bias was found when participants were presented with images first, and later asked to read sentences (Wassenberg & Zwaan, 2010). Sentences that matched the information presented in the images were read faster, providing evidence that sensorimotor information is not only encoded for future sensorimotor activation, but also leads to understanding of linguistic descriptions. This shows an intertwined relationship between an individual's language and how they perceive the world.

Spatial location is encoded and recalled during mental simulation. Eye tracking studies found that people focus systematically on regions of space when recalling images (Padakannaya et al., 2002); following this, objects are recognized faster when presented in their previously observed position (Richardson et al., 2003). This simulation bias extends to abstract concepts and image schemas with concepts like *more* and *better* being recognized faster when presented in the top half of the visual field (Zwaan & Yaxley, 2003).

Research on implicit representations during language comprehension show that mental simulation consistently includes representations of implied information. These representations include both physical and abstract information, with abstract information tied to a physical element. The effect is dependent on general comprehension. The bias is

stronger in older adults, who take longer to process information in general. Results are consistent with the simulation theory based on top-down processing, which affects recognition speed and not accuracy (Barsalou, 1999; Zwaan & Pecher, 2012).

### **Movement**

So far, mental representation has been discussed as a stagnant, single-frame occurrence, wherein shape, orientation, location in a scene, and color can all be represented in a snapshot. Representational momentum is the small but consistent error that people make when estimating how far an object has moved along a path, believing that the object has moved slightly further than it actually has (Hubbard, 2005). This error indicates that movement is part of mental simulation, not just perception. Furthermore, movement is predicted to go in a specific direction when there is a clear front to an object. Although not attributed to writing direction, there is also a greater bias for left-to-right momentum in English speakers, hinting at a potential directional bias.

Research on movement in mental simulation provides evidence that simulations are fluid, so when movement is an active element of a simulation the simulation proceeds as we perceive movement on a moment-to-moment basis (Shepard & Metzler, 1971; Halpern & Kelly, 1983). Again, the representations are analog and not high-definition, but these analogs do move in a manner consistent with our experience. Mental rotation shows a correlation between reaction time and the degrees of rotation required to determine if two objects are the same, indicating that mental rotation is a fluid simulation of rotating one object until it either clearly matches or does not match a second object (Shepard & Metzler, 1971). Similarly, even when shown snapshots of an object that imply a consistent path of rotation, people have a tendency to over-rotate, but show no

tendency when the object does not follow a consistent path (Freyd & Finke, 1984). When people perceive and simulate motion they expect consistency, and are biased to believe that objects will move in the direction they are facing (Morikawa, McBeath, & Kaiser, 1992). When asked to recall how far an object has moved along its path (given consistent motion) there is a larger bias for objects going towards the right than to the left among English speakers (in a study with only right-handers) (Halpern & Kelly, 1983). Overall representational momentum shows a greater bias for horizontal than vertical movement and within horizontal movement there is a greater bias for right-to-left movement than left-to-right movement, though studies have only been done using English speaking populations (Hubbard, 2005).

Sentences implying motion towards and away from an individual lead to images being identified faster when their size matches the change that would occur if moving congruent with the sentences implications (Zwaan et al., 2004). For instance, the sentence, *The pitcher hurled the softball to you*, an image depicting the softball followed by a second image depicting a larger softball, would be recognized faster than two same-sized softballs or if a smaller softball followed the first image.

### **Writing Direction**

Research into directional bias has looked into a number of potential factors over the years, including handedness, hemisphere lateralization, and writing direction. Writing direction has emerged as the main determiner of directional bias. Directional bias is a preference for information - in whatever capacity - to move in a certain direction. Writing direction bias manifests itself in people's preference for action to move with the

individual's writing direction. From an early age, writing forms an embodied relationship with time. Time passes as one writes across a page, so the beginning of a sentence occurs earlier than the end. Books usually follow writing direction and usually tell a story of which time is an element, so moving from beginning to end of the book is also marked by the passage of time. Reading requires the reader to move with the direction of the words, which again are attached to passage of time. The most blatant examples of this bias are timelines, which are matched to a person's writing direction (Dahaene, et al., 1993; Boroditsky et al., 2010; Boroditsky & Fuhrman, 2010; Santiago, et al., 2007). This association with time moving in the same direction as one reads and writes and actions having beginnings, middles, and ends forms is part of time mapping onto space as part of cognitive metaphor theory (CMT) (Lakoff & Johnson, 1980). CMT outlines how abstract concepts such as time are mapped onto target domains, such as space to allow for better understanding of the concept being mapped. The constant exposure to writing direction causes a direction bias to occur within this mapping (Suitner & Maass, 2016). In fact, research on English speaking left handers at young ages, show that as they learn to read they show a stronger bias towards left-to-right direction than right handers, which is evidence of extra effort being made to overcome an initial right-to-left direction bias informed by handedness (Suitner et al., 2015). Although direction bias based on writing direction is not a natural phenomenon, the repeated exposure to writing direction primes people to perceive their world in this direction (Nachson, 1985).

Research into writing direction first focused on how it could cause difficulty in second language acquisition of opposite direction languages (Deconchy, 1958). Deconchy found that Arabic speakers showed a right-to-left bias across a number of

experiments, culminating in slower reading of French sentences (especially when exposed to distractions). Deconchy hypothesized this was due to some version of dyslexia brought on by direction preference. In the 1950s, Deconchy was constrained by the theories of the day; however, applying modern theories, this perceived dyslexia fits into current theories of embodiment, blending, and body specificity (Maass, Suinters, & Deconchy, 2014). Research conducted since the rediscovery of Deconchy's work has focused on the effects of writing direction bias on choice, creation, and interaction.

Choice-based studies focus on choosing from preselected depictions of action and time and have found a bias for depictions that match writing direction. In these studies, the selections show that people perceive writing direction congruent depictions as the correct representations, which correlates to experience in the mental representation process. Creation studies are often very similar to perception studies, but ask the participants to draw the image or images themselves. These represent the mental imagery portion of the mental representation process. Interaction studies involve participants interpreting information that is presented to them and describing what they perceive. Studies have found that participants describe scenes in their writing direction, actively creating writing direction biased information for others to comprehend. People also rate implied or actual action going in their writing direction as subjectively higher in a variety of categories, further solidifying their preference for writing direction congruent action. While studies on writing direction have covered a lot of territory, there are currently no studies that look at the presence of writing direction bias during mental simulation. Studies show preferences for experience, encoding, and mental imagery that are writing direction congruent, but mental simulation is an unconscious act that depends on a fuzziest

representation of information, so it remains to be seen whether this bias is an active component during simulation or is only recalled later during mental imagery, when information is more vividly recalled.

## **Input**

**Embodiment.** Reading and writing are inherently embodied actions. Writing requires use of the arm to manipulate information into existence via words, and these words are written in a specific direction depending on the language being used. Reading requires sensorimotor engagement and requires scanning for information in a particular direction. These actions begin before a child even begins to start reading and writing (Tolchinsky-Landsmann & Levin, 1985). During pretend play, children pretend to read and write in their future writing direction as they mimic what they have seen from those around them (Nuerk et al., 2015). This pretend play, in combination with early writing leads to young English left-handers overcompensating for their initial right-to-left biases, drawing objects from left-to-right at an even higher rate than their right-handed counterparts. Both young English left- and right-handers show a left-to-right bias during drawing tasks, meaning that they begin their drawing on the left side and progress to the right (Maass et al., 2014). By an early age the action of writing and reading from left to right creates a direction bias that is stronger than any potential natural bias towards an individual preferred hand.

Eye-tracking shows that people scan in their writing direction. Reading and writing being a consistent part of one's environment leads to a preference for scanning in that direction (Abed, 1991). Additionally, scanning has been found in areas from basic spatial exploration to artwork to search tasks. (Elkind & Weiss, 1967; Chokron & De



Agostini, 2000; Zazzo, 1950; Maass et al., 2014) As discussed above, this directional bias leads to an association with the beginning side of an eye scan being mapped with space, creating an association with earlier time; likewise, the opposite holds at the end of a scan. Phenomena like mental timelines and number lines, along with the SNARC effect fit this writing direction bias in both left-to-right and right-to-left languages (and top-to-bottom languages, but those are outside of the scope of this study) (Fuhrman et al., 2011; Dahaene et al., 1993; Bonato, Zorzi, & Umiltà, 2012; Shaki et al., 2009).

**Choice.** In mental representation, the first part of the process is experience, which is intertwined with encoding. Limited attention resources mean that people can only focus on some elements of any particular experience. Writing direction plays a significant role in determining what elements are attended to when determining what image(s) represent people's expectations of a particular action. These studies show that direction can be an experience element. Preference for action that is congruent with writing direction leads to a confirmatory bias where experiences that are writing direction congruent are acknowledged as being so, while incongruent occurrences lead to focus on different elements of the scene or regarding the experience as abnormal in some way.

When presented with multiple images that could possibly represent a sentence with an agent-patient relationship, people prefer the action to progress congruent with their writing direction, so for left-to-right writers, the agent would be on the left and the patient on the right (Chatterjee et al., 1995). In one study, agents are selected as mapping with an arrow that matches writing direction, while being the patient of an action maps with an arrow in the opposite of writing direction (Suitner, Maass, & Ronconi, 2015). In another study using an array of four somewhat hidden faces, people first identify a face

on the side of the image where their writing direction begins (Zazzo, 1950; Maass et al., 2014). Additionally, images that depict the progression of a scene are preferred to be arranged in the order congruent with an individual's writing direction (Maass et al., 2014, Boroditsky, 2000).

When given the option to choose, people show a clear preference for depictions of action that are congruent with their writing directions. Even concepts of action are preferred to match writing direction bias. People show a preference to identify direction as an element that reflects the meaning of an experience.

## **Output**

**Creation.** Creation studies involve drawing an action or interaction. This is a representation of mental imagery because the drawings are a conscious act. Drawing tasks show that from preschoolers to adults, across left-to-right and right-to-left languages there is a preference to depict action moving congruent with one's writing direction and to represent agentic parties as congruent with writing direction.

Pre-school children draw their parents with the more agentic parent congruent with their writing direction and the less agentic parent facing against writing direction (Suitner, Carraro, & Maass, 2008). Generally, school children draw in their writing direction and this preference is shown to continue into adulthood (Maass et al., 2014, Chatterjee et al., 1995). Interacting targets are depicted in line with respective script direction (Dobel, Diesendruck, & Bolte, 2007; Maass, Suitner, & Nadhmi, 2014). When fluent in a second language, instruction in that language leads to a preference for depicting interaction in that language's writing direction. The surrounding cultural language does not change preference, only the instructional language. There is a larger

overall effect of writing direction preference in one's native language (Maass & Russo 2003).

In their book giving an overview of the effects of writing direction, Maass, Suitner, and Deconchy (2014) include an image with a number of childrens' toys that have the toys set up so that they are facing towards the right, which is congruent with the writer's writing direction (p.16). This image was included only as an example for an anecdote about one of the writer's children, but objects were still staged with a writing direction bias.

The arts also feature directional cues and biases. In theatre productions, there is a common tactic of introducing antagonistic characters from the stage direction that goes against people's preferred writing direction (Maass, et al., 2014). This is a creative choice used to provoke a particular reaction. Painters show a correlation between how passive they perceive someone sitting during a portrait and the likelihood that this person will be painted against the painter's writing direction (McManus & Humphrey, 1973; Gordon, 1974; Grusser, Selke, & Zynca, 1988; Conesa, Brunold-Conesa, & Miron, 1995; Suitner & Maass, 2007; Latto, 1996). In both left-right and right-left languages, painters prefer to paint the man in the more agentic position in paintings featuring both a man and a woman; this reflects a social norm in which men have long been considered the more agentic gender, even if this is not in line with current interpretations (Suitner & Maass, 2007). Painters also prefer self-portraits to be writing direction congruent (McManus & Humphrey, 1973; Suitner & Maass, 2007; Latto, 1996). Soccer fans show a similar bias when asked to fill in a pitch with their team's lineup and their team's rival's lineup representing their team in line with writing direction preferences (Maass et al., 2015).

When creating images, people exhibit a preference to create content in line with their writing direction - not just the figures themselves, but also any action staged within the image. This preference can be observed even when placing objects on shelves or staging for a photograph (Maass, Suitner, & Deconchy, 2014). Images or actions are often created with good or agentic people in a writing congruent direction and bad or passive people against writing direction. Given the time to create rich depictions, there is a clear writing direction bias among study participants.

**Interaction.** Studies that delve into interaction involving indicate that people represent information congruent with their writing direction either by the way they chose to interact with a given environment or how they describe the environment to others. A number of studies take this a step further and show that there is a link between writing direction and aesthetic preferences. Though both have only been measured outside of mental simulation, these results show a strong preference for representing the world in one's writing direction.

When shown images with multiple people in a line, participants verbally identify those in the picture in a manner congruent with their writing direction (Maass et al., 2014). A second task that asked students to use sticks to fill in holes in a box that were arranged equidistant along a horizontal plane, found that students preferred to fill in the holes congruent with their writing direction in both left-right and right-left language populations (Maass et al., 2014; Bettinsoli 2010; Bettinsoli, 2011). In both tasks, attempts to persuade students to interact against writing direction using cues (via attention-grabbing stimuli or forced perspective, among other things) only reduced directional bias to chance levels, as opposed to creating a reverse bias. Even when cued, people are

reluctant to go against writing direction. During a memory recall task, objects were arranged in a grid and participants were given time to observe objects, before being asked to recall objects by filling the grid back from memory. A writing direction bias was shown in both left-to-right and right-to-left language participants with a primacy bias for objects at the starting point of their writing direction and a recency bias at the end point (Maass et al., 2014; Bettinsoli, 2011, Padakannaya et al., 2002). When interacting with their environment, participants show a clear preference for interacting in a manner congruent with their writing direction.

Strong aesthetic preferences have been found for writing direction congruent images and actions. The constant presence of writing and reading in our lives may create a very strong mere exposure effect, which leads to perceptual fluency for images and actions that are congruent with writing direction (Reber, 2011; Zajonc, 1968; Topolinski, 2010). This fluency could lead to aesthetic preferences as well as preferences for direction during mental simulation. Aesthetic preferences have been found for artwork, spatial exploration and agency (Elkind & Weiss, 1967; Chokron & De Agostini, 2000; Maass et al., 2014; Suitner, Maass, & Ronconi, 2017). These preferences have been shown to exist in cross-linguistic studies (Nachson, Argaman, & Luria, 1999; Chokron and De Agostini, 2000, Heath, Mahmasanni, Rouhana, & Nassif, 2005; Maass, Pagani, & Berta, 2007). In a neutral scene, the person on the left for left-to-right languages was judged to be more instrumental and dominant in the interaction (Pucinelli, Tickle-Degnen, & Rosenthal, 2006). Italian and Arabic speakers judged static images of cars as moving or faster when facing in line with writing direction and stopped or slower when facing the against writing direction (Maass et al., 2014). Writing direction congruent

scenes are judged as easier to understand (Maass et al., 2014). Even simple arrows are judged more aesthetically pleasing when writing direction congruent and facilitated arm approach actions, while direction incongruent arrows facilitated arm extension (Phaf & Rotteveel, 2009).

Actions themselves are rated more highly when writing direction congruent. Runners and cars are judged to be faster when facing the viewer's writing direction in images (Suitner et al., 2008, Maass, Suitner, Boschetti, & Tomicelli, 2015). Cars were also judged to be more powerful (Maass et al., 2015). Images of sports scenes were judged to be faster and more pleasant when the action seemed to be writing direction congruent (Maass et al., 2015). Maass, Pagani, & Berta (2007) found that videos soccer goals were rated as more beautiful, stronger, and faster when writing direction congruent than their mirror videos for both Arabic and Italian speakers. The same study also found videos of fistfights to be rated as more violent, traumatizing, and stronger when the strikes were writing direction congruent.

Writing direction not only creates basic aesthetic preferences for action and implied action, but also facilitates judgements of the quality of the action being depicted or implied. Although these preferences use both top-down and bottom-up processing, the strong results indicate that the preferences may originate during mental simulation, which would prime participants for action in a specific direction.

### **The Present Study**

Work on mental representation dovetails with work on perceptual symbol systems and writing direction, yet these intersections have to date gone unstudied. Mental

simulations require highly salient elements of experience in order for them to attract humans' limited attention resources. Writing direction has been shown to be an important factor for experience, as when scanning the environment. The preference is also resistant to cues intended to distract or reorient, showing that it is very likely attended to, even unconsciously.

Mental simulations have been found to represent shape and orientation. Objects that are in motion or preparing to be in motion typically face the direction in which they will move, and so they should exhibit a distinct shape and orientation. The aesthetic preferences related to writing direction show a clear directional preference for action. Movement should, thus, be part of a simulation, which would mean that the simulation also has some element of directionality.

Directionality is a highly salient element of experience and mental imagery, which have been precursors to other elements that have been represented when implied during language comprehension. Writing direction creates a directional bias that manifests during mental representation of information that implies action.

Building from previous studies that measured mental simulation, the present study uses a reaction time experiment to measure directional bias in mental simulation. Participants were presented with oral sentences to comprehend and then presented with an image that either matches the object discussed in the sentence or does not. Images will be either congruent or incongruent with the participants' writing direction. The study only includes fluent English speakers. The hypotheses are as follows:

1. Congruent matching images will be responded to faster than incongruent matching images.

2. There will be no effect for handedness, age, or gender.
3. There will be no difference in accuracy between congruent and incongruent matching images.
4. For non-matching images there will be no difference in accuracy, in terms of correctly rejecting, for congruent and incongruent images.

## Method

### Participants

Fifty-five college students were recruited from Case Western Reserve University and the surrounding area for this study. One participant was removed because of accuracy below eighty percent (19 males, 34 females, 1 not identified; 46 pursuing bachelor's degrees, 5 bachelor's degrees, 3 master's degrees; 4 left handers, 46 right handers, 4 ambidextrous). Fifty-four participants were under 24 years old and one participant was between the ages of 45 and 54. Participants were recruited via in-class announcements and posts on the Language and Cognition Lab Experiment Management System. Students were given extra credit or \$5 for their participation.

### Materials

**Handedness measure.** The Edinburgh handedness survey was used to measure whether participants were left or right hand dominant and was given to all participants after the experimental trials (Oldfield, 1971). The survey consists of one question prompt (*For the set of questions please indicate which hand you prefer to use for each activity*) and fifteen items with five response options each: Left; Right; No preference; Usually Left, but sometimes Right; and Usually Right, but sometimes Left (*see Appendix A*).



**Demographics.** The demographics questionnaire consists of seven items and was given to all participants. The questionnaire asks questions concerning gender, age, education, and language fluency (*see Appendix B*).

**Mental Simulation Task.** To measure the effects of writing direction on mental simulation, a go/no-go task was designed in SuperLab 5.0. The task consisted of eight practice trials followed by eighty experimental trials mixed with forty filler trials. Each trial consisted of five steps: fixation cross, sentence, fixation cross, image, and response (*see Appendix C*). The first fixation cross was displayed on the screen until the participant pressed the spacebar initiating the trial. This step was done in lieu of the more traditional design which allows breaks after a set number of trials; this was chosen so that participants could take a break at any point that they felt tired, overwhelmed, or confused, as opposed to only having that opportunity at fixed intervals. Upon pressing the spacebar, the fixation cross disappeared and a sentence was delivered via the computer speakers (participants were offered headphones, which only one participant chose to use). The experimental sentences were simple action sentences consisting of three to four words and three to seven syllables that were created using the text-to-speech function in TextEdit 1.12 and converted to .mp4 files. Sentences were presented orally to account for any priming effects of reading the sentences from left to right. Sentences consisted of *The* followed by a noun denoting either a person (man, girl, skateboarder), animal (lion, monkey, shark), vehicle (ship, cruiser) or object (missile, wand) and an action verb (runs, walks, sails, casts) that implies horizontal movement. After the sentence, a fixation cross reappeared for 250ms, before an image was presented on the screen. The images were black profile silhouettes facing either towards the left or the right created in Google

Drawing and converted to .bmp files. Participants pressed the spacebar if the image matched the subject of the sentence and waited 2000ms without pressing anything if the image did not match. After pressing the spacebar or after 2000ms, the next trial began. Filler sentences and images were taken from Zwaan, Stanfield, & Yaxley (2002).

Four versions of the experimental trials were created, so that every sentence would be presented with a congruent, matching image; incongruent, matching image; congruent, non-matching image; and incongruent non-matching image (Appendix D). *Matching* and *non-matching* refers to whether the image represented the noun presented in the sentence. *Congruent* and *incongruent* refer to the direction the image was facing, with congruent images facing towards the right. In each version, each sentence was presented once. Of the eighty trials, twenty were congruent matching, twenty were incongruent matching, twenty were congruent non-matching, and twenty were incongruent non-matching. This resulted in forty matching trials where a pressing the spacebar was appropriate and forty non-matching trials where the appropriate response was no response.

The filler trials consisted of twenty matching (image matched the sentence) trials (spacebar response appropriate) and twenty non-matching (image does not match sentence) trials (no response appropriate). Of the twenty matching trials, ten were shape congruent (the shape was congruent with the shape implied by the sentence) and ten were shape incongruent (shape incongruent with shape implied by the sentence).

## **Procedure**

Participants were welcomed to the experiment at the door of the Language and Cognition Lab. Participants signed a sign-in sheet indicating whether they wished to

receive extra credit or \$5 for completing the experiment. After signing the proper sign-in sheet, participants were led to the computer, where one of the four experiment versions was already loaded and the informed consent document was presented on the screen (Appendix E). Upon agreeing to participate, participants were presented with instructions for the practice trials; after each practice trial, participants received feedback. Before beginning the experimental trials, participants had the opportunity to ask any questions and were again presented with the task instructions that stressed responding quickly without sacrificing accuracy, and that the participant would no longer receive feedback after each trial. The experimental and filler trials were presented randomly. Following the experimental trials, participants completed the Edinburgh Handedness Survey and demographics questionnaire. Finally, participants were debriefed and thanked via a final screen display (Appendix F). Participants were given the opportunity to ask any final questions and given compensation if they indicated they wished to receive \$5. For participants receiving extra credit, their professor was emailed to indicate that the student had completed an experiment.

## **Results**

### **Reaction Time**

An one way repeated measures analysis of variance was conducted to compare the effect of image direction on median reaction time for matching images in congruent and incongruent writing direction conditions. Median reaction times were used in accordance with previous studies on mental simulation. (Zwaan & Pecher, 2012) There was a significant main effect of image direction,  $F(1,52) = 4.19, p = .046, \eta^2 = .075$ , with faster

reaction times for congruent ( $M=636.88\text{ms}$ ,  $SD=120.75$ ) than incongruent ( $M=646.19\text{ms}$ ,  $SD=126.10$ ) images (See Table 1). This result supported the hypothesis that writing direction congruent matching images would be responded to faster than incongruent writing direction matching images. There was a significant interaction effect for Congruent x Gender,  $F(1,52) = 7.50$ ,  $p = .008$ ,  $\eta^2 = .126$ , but no main effect for gender,  $F(1,52) = .16$ ,  $p = .70$ ,  $\eta^2 = .003$ . No significant differences were found for handedness, which supports the hypothesis. Age was not tested because there was only one participant over twenty-four years of age.

### **Accuracy**

A paired-samples t-test was conducted to compare accuracy for matching images in congruent and incongruent writing direction conditions. There was not a significant difference in the accuracy for congruent ( $M=.95$ ,  $SD=.01$ ) and incongruent ( $M=.96$ ,  $SD=.01$ ) writing direction conditions;  $t(53) = -1.64$ ,  $p = 0.11$ . This result supported the hypothesis that congruent writing direction images would not have different accuracy scores than incongruent matching images. There was also no significant difference found for accuracy in congruent versus incongruent non-matching trials.

### **Filler Trials**

An one way repeated measures analysis of variance was conducted to compare the effect of image shape on median reaction time for matching images in congruent and incongruent shape conditions. There was a significant main effect of image shape,  $F(1,52) = 4.19$ ,  $p < .001$ ,  $\eta^2 = .269$ , for congruent ( $M=618.04\text{ms}$ ,  $SD=168.78$ ) and incongruent ( $M=676.62\text{ms}$ ,  $SD=196.18$ ) shape conditions (See Table 1). Though not directly related to our hypotheses, showing that the filler trials were congruent with

previous results increases the likelihood that the present study was on track to use a representative sample.

### **Discussion**

All of the main hypothesis were supported along with an unexpected finding of an interaction between image congruence and gender. The main hypothesis that people would be faster to identify congruent images than incongruent images was supported, albeit with a less robust difference in reaction times than previous studies into mental simulation and the filler trials of the current study. Small, but significant, reaction time differences are expected for mental simulation tasks because simulation predicts a particular outcome, but does not prevent alternative outcomes from being understood. There was no significant difference in reaction time due to handedness, which supports writing direction over handedness as the cause of direction bias. (Age was not studied because there was no significant age difference among the participants.) There was no significant difference for accuracy in identifying matching images or rejecting nonmatching images regardless of image direction, which is in line with mental simulation predicting a particular outcome, but not preventing an alternative. When observing the environment, a prediction is quickly rejected in the face of observed information leading to small reaction time differences and no difference in accuracy. The results of this study indicate that writing direction results in a directional bias during mental simulation. Limitations, future directions, and implications of these results are discussed.

The limitations of the present study are sentence length, image characteristics, and lack of movement. The experiment sentences were between three and four words,

whereas the filler sentences were seven to eight words. The shorter sentences could have caused lower levels of engagement leading to less simulation. This could explain the smaller reaction time difference. In the future, longer sentences, such as "The man runs the race" or "The man runs across the field," should be tested. The images used in the study attempted to match the verb in the sentence, but silhouettes cannot convey many of the subtleties of motion. Previous research found that only dynamic images of motion elicited a writing direction response bias when participants were asked how fast the person or object in the image was moving. These dynamic images were created by taking photos of people and objects that were actually in motion as opposed to just posing to look as if they were (Suitner, Maass, Cardinale, et al., 2015). The outset study would have benefited from creating and using a similar dynamic set of stimuli. Finally, although actual movement was implied by the sentences, the stimuli used were only images implying motion. An alternative to dynamic images would be to use videos, which would better match the simulation of motion implied by the sentences. The limitations in the current study could explain the small, but significant, reaction time difference. Using longer sentences and more dynamic stimuli in future studies could lead to reaction time differences that are more in line with previous mental simulation studies.

The results of this study point to a number of future study directions that could further illuminate the impact of direction bias on mental simulation. First, as discussed above, studies that account for the limitations of the present study would be necessary to further validate results and potentially bring them more in line with previous findings. If the base results are replicated, the next step would be to translate the sentences into a right to left language (Arabic and or Hebrew) and test fluent speakers to determine

whether the bias is truly due to writing direction or if the rightward direction bias is pervasive across language and the result is more in line with handedness or hemisphere asymmetry theories. Studies on bilingual left to right and right to left speakers would look at how quickly the writing direction bias flips or if it is stronger for one's native language. Research into people who are at different stages of learning their first opposite direction language would illuminate when the new direction begins to influence mental simulation and if this influence coincides with any major language milestones.

Outside of establishing the relationship between mental simulation and writing direction, future studies would do well to investigate the effects of direction simulation bias on real life situations that require split second choices that may rely on direction information. Airport security uses luggage scanners that move in either direction, and the people doing the scanning are notoriously bad at identifying contraband. Experiments could analyze how the direction of scanning effects identification rate and determine if there is a scanning direction that would lead to significantly better identification rates. From police officers to military personnel, people in dangerous lines of work are asked to make split second decisions regarding the threat posed by those around them. Often these people are required to identify whether a potential threat is holding or pulling out a weapon or a nonweapon. Because this determination must be made very quickly, research into mental simulation should look into whether experts in these fields are faster at identifying threats that proceed in one direction over another, which could inform people in these fields to position themselves so that action will more likely occur in the direction that leads to faster identification. Less important, but potentially more valuable, athletes over a wide range of sports make split second decisions. Studies on athletes could look

into bilingual speakers of both left to right and right to left languages to see if they process information faster in both directions than a single direction language speaker. For some sports, there are positions that require information from a specific direction to be processed more quickly, such as cornerbacks in the NFL. Expertise studies of cornerbacks could identify if direction bias plays a role in how quickly they process information and if learning a opposite direction language could lead to faster processing. The present study has implications for a number of different areas with cognition research. First, the present study provides more definitive evidence that mental simulation is a modal and dynamic process that relies on previous experience. Because direction bias comes from a separate realm of experiences than the experiences reactivated by the sentences, this is clear evidence that simulation combines experiences and is not an amodal representation independent of experience. This is also further evidence of the role of embodiment in experience. Writing direction causes people to scan the environment in a particular direction, leading to both observing the environment in this direction and simulating in the same direction. The body directly affects how information is both created and processed. Finally, the results of this study shed some light on the generic space in blending theory. Often depicted as the first space that provides information to two or more input spaces based on those spaces shared traits, this study indicates that the generic space may hold its own independent information that is utilized between the input spaces and the completion of the blend. Essentially, when creating a simplex blend for information, such as "The man runs," the generic space contributes the directional bias that allows the blend to be completed and run. Further



analysis of this phenomenon could provide the experimental evidence that has so far eluded blending theory.

Writing direction leads to a directional bias during mental simulation. This further solidifies modal mental simulation theories. The bias also supports embodiment and blending theories. Future research into this phenomenon could strengthen this support while also exploring the real world implications of this bias.

If a tree falls in the forest, it may or may not make a sound, but it definitely falls in the same direction this sentence is written.

## Appendix A

## Edinburgh Handedness Survey.

For the set of questions please indicate which hand you prefer to use for each activity:

1. Writing
  - 1) Left
  - 2) Right
  - 3) No Preference
  - 4) Left, but I sometimes use my Right
  - 5) Right, but I sometimes use my Left
2. Drawing
3. Throwing
4. Using Scissors
5. Using a Toothbrush
6. Using a Knife (w/o a fork)
7. Using a Spoon
8. Using a Broom (upper hand)
9. Striking a Match
10. Opening a Box (holding the lid)
11. Holding a computer mouse
12. Using a key to unlock a door
13. Holding a Hammer
14. Holding a Brush or Comb
15. Holding a Cup while Drinking

## Appendix B

## Demographics

Age:

- 1) 18-24
- 2) 25-34
- 3) 35-44
- 4) 45-54
- 5) 55-64
- 6) 65+

Gender:

- 1) Male
- 2) Female
- 3) Other

What's the highest level of education you've completed?

- 1) No schooling completed
- 2) 8th grade
- 3) Some high school (no diploma)
- 4) High School
- 5) Associate's Degree
- 6) Currently pursuing Bachelor's Degree
- 7) Bachelor's Degree
- 8) Master's Degree
- 9) Doctoral Degree (PhD, JD, MD, etc.)

Is English your first language?

- 1) Yes
- 2) No

If no, what language is?

Are you fluent in any languages other than English?

- 1) Yes
- 2) No

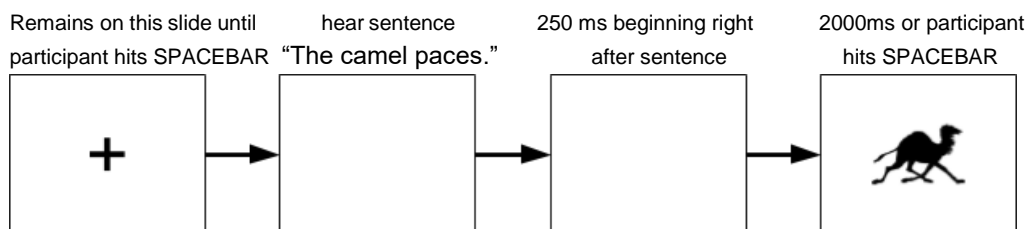
If yes, which language(s)?

## Appendix C

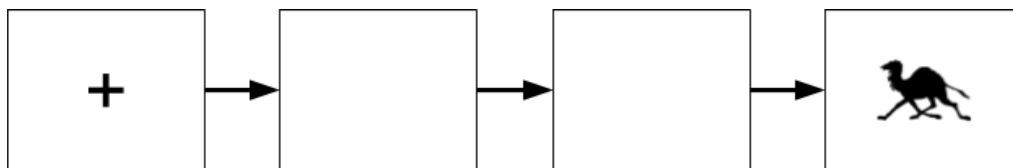
## Trial Conditions

**Instructions:** For each trial, you will hear a sentence followed by an image. If the image matches the subject the subject of the sentence that you just heard, press the SPACEBAR. If the image does not match, do not press anything and the next trial will begin shortly. Your objective is to respond as quickly and accurately as possible. Again, **ONLY PRESS THE SPACEBAR IF THE IMAGE MATCHES THE SUBJECT OF THE PREVIOUS SENTENCE**, otherwise do nothing

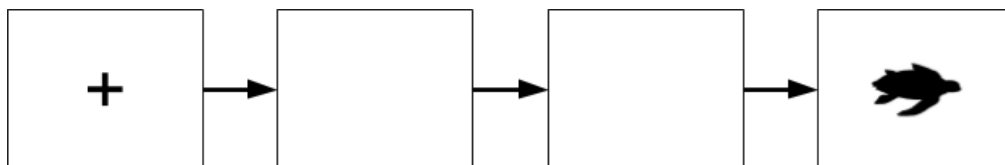
**Congruent Matching:** Images matches sentences and writing direction (should press SPACEBAR)



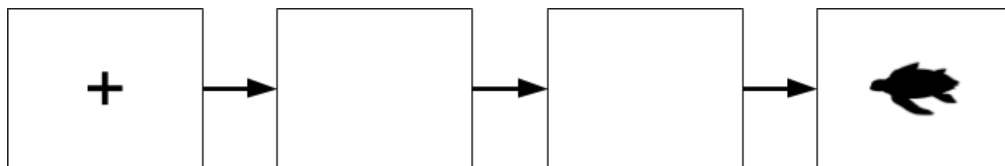
**Incongruent Matching:** Image matches sentence, but not writing direction (should press SPACEBAR)



**Congruent Nonmatching:** Image does not match sentence; does match writing direction (No Response)



**Incongruent Nonmatching:** Images does not match sentence or writing direction (No Response)



## Appendix D

### Informed Consent

You are being asked to participate in a research study about image recognition. You were selected as a possible participant because you responded to an advertisement about the study. Please read this form and ask any questions you may have (by emailing kevin.newhams@case.edu) before agreeing to participate in the research. This study is being conducted by researchers at Case Western Reserve University.

#### **Background Information**

The purpose of this research is to find out more about the relationship between writing direction and mental imagery.

#### **Procedures**

If you agree to be a participant in this research, we would ask you to do the following things: close all tabs not related to this study that you have open, be prepared to focus on this study for the next thirty minutes, & **TURN YOUR VOLUME UP TO YOUR PREFERRED LISTENING VOLUME** (headphones can be used). In the study, we would ask you to listen to short sentences and answer a question about each one, then fill out a short survey.

The entire study will take about 45 minutes.

#### **Risks/Benefits**

This research has no foreseeable risks. There are no direct benefits for participating in this study.

#### **Compensation**

Upon completion of the study, you will be compensated with \$5 or extra credit for your time. This compensation will not be prorated. If you withdraw from the study at any time you will not be compensated.

#### **Confidentiality**

The records of this research will be kept private. In any sort of report that may be published, no information that makes it possible to identify an individual participant will be included. Research records, will be kept on password protected computers, and access will be strictly limited to the researchers, the University review board responsible for protecting human participants, and regulatory agencies.

#### **Voluntary Nature of the Study**

Your participation in this study is completely voluntary. If you choose not to participate, it will not affect your current or future relations with the University. There is no penalty or loss of benefits for not participating or discontinuing your participation. Contacts and Questions The researcher conducting this study is Kevin Newhams and Todd Oakley. If you have any questions, concerns or complaints about the study, you may contact Kevin at kevin.newhams@case.edu or Todd Oakley at todd.oakley@case.edu, (216) 368-2595.

If the researchers cannot be reached, or if you would like to talk to someone other than the researcher(s) about; (1) questions, concerns, or complaints regarding this study, (2) research participant rights, (3) research-related injuries including distress or anxiety from the study, or (4) other human subjects issues, please contact Case Western Reserve University's Institutional Review Board at (216) 368-6925 or write to: Case Western Reserve University; Institutional Review Board; 10900 Euclid Avenue; Cleveland, OH; 44106.

You can print a copy of this form for your records.

**Statement of Consent**

I have read the above information. I have received answers to the questions I have asked. I consent to participate in this research. I am at least 18 years of age.

## Appendix E

### Study Debrief

This study is concerned with the way we process sentences and simulate actions. Previous studies have found people show a preference for processing information in the same direction as their first language writing direction. Separate experiments have found that the mental images people form are clear and defined, and that these images change depending on the information that the person is presented.

How was this tested?

In this study, you were asked to perform two tasks—a reaction time task and a brief survey. All participants performed these same tasks in the same order. The groups differed in the order that each trial of the reaction time task was presented and what images followed each sentence.

Hypotheses and main questions:

We expect to find that participants identify images that have an orientation that is directionally congruent with the participant's native writing direction faster than images facing the incongruent direction. We also expect participants to mistakenly identify images as matching the presented sentence more often when the images are non-writing direction congruent.

Why is this important to study?

This study will help to define the relationship between the brain, language, and culture. Specifically, the study will show how language direction creates bias in people to predict action proceeding in a particular direction. This bias could have many effects on how people interact with the world, which will be explored in future studies.

What if I want to know more?

If you would like to receive a report of this research when it is completed (or a summary of the findings), please contact Kevin Newhams at [kevin.newhams@case.edu](mailto:kevin.newhams@case.edu) or Todd Oakley at [todd.oakley@case.edu](mailto:todd.oakley@case.edu).

If you have concerns about your rights as a participant in this experiment, please contact the Case Western Reserve University's Institutional Review Board at (216) 368-4514.

**Thank you again for your participation. Please press the SPACEBAR to complete the study.**

Table 1

*Overview of Congruent and Incongruent Effects (Median RTs) for Current and Previous Studies.*

	N	Congruent (SD)	Incongruent (SD)	Difference	<i>p</i>
<b>Direction</b>					
Present Study	54	636.88 (120.75)	646.19 (126.10)	9.31	.046
<b>Shape</b>					
Present Study	54	618.04 (168.78)	676.63 (196.18)	58.59	< .001
Zwaan & Pecher (2012)	176	979 (356)	1036 (404)	57	.0001
Zwaan, et al. (2002)	42	697 (202)	761 (210)	64	.0008



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