HORIZONTAL ASYMMETRIES DERIVED FROM SCRIPT DIRECTION: CONSEQUENCES FOR ATTENTION AND ACTION

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RESUMO

A direção de leitura e escrita estabelecem uma trajetória preferencial de exploração do espaço que é reforçada por diversas regularidades culturais consistentes com essa direccionalidade. A correlação espaço-movimento cria um esquema para a ação que enviesa a representação da agência humana, estendendo-se à representação de outros conceitos abstratos que não possuem bases sensoriomotoras. A dimensão horizontal é recrutada para melhor compreender estes conceitos, sendo ancorados de acordo com a direção de escrita e leitura da nossa língua. A assimetria espacial que esta direccionalidade induz constitui um contributo crucial para a área do *embodiment*, tendo sido demonstrado que afeta processos sociais e cognitivos. Contudo, os processos específicos que estas assimetrias ativam permanecem pouco explorados. Em sete estudos, esta dissertação investiga de que forma as assimetrias espaciais afetam inferências sociais e a performance visuo-motora para com estímulos ancorados na dimensão horizontal.

O primeiro estudo indica que inferências sociais relacionadas com agência são preferencialmente atribuídas a faces de perfil orientadas para a direita (versus esquerda). Em duas experiências, o segundo estudo mostra que faces orientadas para a direita servem como pistas para a orientação de atenção. Faces orientadas para a direita, que traduzem a direção utilizada para representar a agência humana, facilitam a atenção para e deteção de alvos no campo visual direito, comparativamente a faces orientadas para a esquerda no campo visual esquerdo. No terceiro estudo, as faces foram substituídas por palavras temporais auditivas e visuais, que se sabe serem ancoradas horizontalmente. A assimetria espacial foi testada em duas experiências em comunidades com direções de leitura e escrita opostas (Português e Árabe). Observou-se uma ancoragem contrária do conceito abstrato ‘tempo’ entre as duas amostras (Português: passado-esquerda/futuro-direita; Árabe: passado-direita/futuro-esquerda). Adicionalmente, uma performance assimétrica reversa entre as duas comunidades linguísticas confirma que o mapeamento do tempo é enviesado pelos hábitos ortográficos e pela representação cultural da agência humana. Isto é, palavras temporais que coincidem com a direção induzida por ambos os sistemas de escrita (i.e., palavras relacionadas com futuro), dão origem a vantagem à direita na amostra Portuguesa, e vantagem à esquerda na amostra Árabe. O quarto estudo estendeu estes resultados à categoria da política, tipicamente representada através de coordenadas de esquerda e de direita. Respostas manuais e atencionais foram mais rápidas para alvos localizados à direita após terem sido apresentadas termos políticos de direita (versus alvos à esquerda após termos políticos de esquerda), que correspondiam à direção em que habitualmente se representa movimento. O quinto e último estudo demonstrou que a apresentação de palavras temporais simultaneamente com um tom auditivo não-espacial impede os efeitos de emergirem. Estas pistas bimodais revelaram as condições limitativas dos efeitos da assimetria espacial.

Em conclusão, esta dissertação demonstra que existe uma propriedade genérica de movimento que deriva da direção ortográfica e que é transversal à representação de estímulos distintos, em várias tarefas e modalidades sensoriais. Estes resultados oferecem uma perspetiva mais abrangente sobre o impacto prevalente que uma característica da língua aparentemente irrelevante tem em processos cognitivos fundamentais de perceção, atenção, e julgamento.

ABSTRACT

The directional activities of reading and writing have been shown to ground a preferential trajectory when scanning space. This horizontal directional formation is further reinforced by other cultural regularities that overlap with it. This space-movement correlation creates a left-right (or vice-versa) schema for action that biases the representation of human agency and extends to the representation of other abstract concepts lacking experiential sensorimotor bases. Consequently, the horizontal dimension is recruited to reason about abstract concepts that are mapped congruently with one's dominant reading and writing or script direction. The spatial asymmetry that this combined directionality induces is a core finding in the embodiment area and has been shown to affect important social and cognitive processes. However, the specific processes activated by these asymmetries remain unclear. A series of seven experiments are outlined to investigate how spatial asymmetries affect social inferences and visuomotor performance to stimuli anchored in the horizontal dimension.

The first study indicated that a range of agency-related social inferences are preferentially assigned to face profiles oriented rightward (versus leftward). Across two experiments, the second study showed that right oriented faces serve as attention-orienting primes. Rightward faces, which are in line with the direction used to represent human agency, facilitate attention to and detection of targets on the right hemifield, relative to leftward faces and targets on the left hemifield. In the third study, face primes were replaced by visual and auditory time words known to ground horizontally in space. Spatial asymmetries were tested in two experiments with communities holding opposite writing scripts (Portuguese and Arabic). We observed the mapping of time to be reversed between the two samples (Portuguese: past-left/future-right; Arabic: past-right/future-left). Further, a mirrored asymmetric performance between the two linguistic communities confirmed that the mapping of time is biased by orthographic habits and the cultural representation of human agency. That is, time words that coincide with the direction induced by both writing systems (i.e., future-related) gave rise to right-side advantage in the Portuguese sample and left-side advantage in the Arabic sample. The fourth study extended these results to the category of politics, commonly represented through coordinates of left and right. Manual and gaze responses were faster to targets embedded on the right following conservatism-related words (versus the left following socialism-related words) that embody the habitualized rightward movement direction. The fifth and final study demonstrated that presenting time words synchronously with an auditory nonspatial tone impaired cueing effects. These bimodal cues revealed the boundary conditions of the spatial agency bias.

Overall, this dissertation underscores that a generic property of movement that is derived from orthographic direction underlies the representation of very distinct stimuli across tasks and sensory modalities. These findings offer a broader perspective on the pervasive impact a seemingly irrelevant feature of language has on fundamental cognitive processes of perception, attention, and judgment.

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Chapter I. Theoretical Overview

The premise under which the present dissertation proceeds is that cognition is socially tuned and situated by contextual forces (Smith & Semin, 2007) and therefore is not dictated merely by human organic architecture. Entrenched cultural routines may exert additional pressures on our genetic programming and alter basic cognitive processes expected to be invariant from a biological point of view.

The use of written language is a fine example of the intersection between the urge for spoken communication and the cultural necessity to preserve and transmit information across generations. From utterance to text, the lateralization of written language arose as a natural consequence of the geographical diversity of existing writing systems. Practically all writing systems that depend on the visual rendition of phonemes (alphabetic writing systems) are horizontally laid out (contrary to pictographic scripts), while a striking portion of these orthographies includes markings for vocalic sounds and is written towards the right (de Kerckhove & Lumsden, 1988). The particular aspects of a language, for example its script, alter the nature of knowledge stored and reused and engage cognition differently, affecting reasoning in tasks rather remote from structured literacy activities (Havelock & Havelock, 1967; Olson, 1977). Thus, script directionality provides a fairly constant, spatially predictive pattern; a feature of language that can be selected as a benchmark for testing the relation between reading/writing and important cognitive processes.

Reading and writing direction has been proposed to symbolically represent agency and its correlates (Maass & Russo, 2003; Suitner & Maass, 2016). Since a wide range of abstract concepts exists, this same horizontal trajectory necessarily serves to represent other concepts that lack a sensorimotor link with the physical environment, such as time and politics (Boroditsky, 2011; Farias et al., 2013; Santiago et al., 2007). Horizontal spatial coordinates accommodate diverse abstract concepts that are best comprehended and conveyed through their link to perceptual experiences and properties of the physical world (i.e. space) (Landau et al., 2010). The resulting embedded spatial preferences and their outcomes are thus shared by all these categories. In addition, attention unfolds laterally in the same direction as the culturally consolidated language script (Suitner & Maass, 2016). In the case of Western languages, this is a left-to-right bias. In languages such as Arabic or Hebrew, the bias evolves from right-to-left. Therefore, people's expectations about events in space, for example where events start (and end), are inevitably guided by the cultural regularities enforced by script direction (Chokron & Imbert, 1993; Spalek & Hammad, 2004, 2005). These spatial biases are generally subtle and malleable, which is reassuring from an applied perspective. A rigid and stable association between a specific trajectory and specific locations in space would be dysfunctional for humans and would not allow for the much-needed flexibility that is required for an optimal interaction with the social and physical world (Maass et al., 2009). The magnitude of spatial biases is volatile and strongly dependent on contextual goals and demands, which reinforces the nature of human cognition as socially situated.

In any case, the spatial asymmetry that this directionality induces in perceivers is a core finding in the embodiment area and has implications for perception, attention, and memory (Suitner & Maass, 2016). However, the specific attentional processes activated by these spatial asymmetries remain unclear as do their consequences concerning expectations about social and non-social targets. This dissertation investigates how the asymmetrical practices of reading and writing may create an embedded pattern of response for generalized action (i.e. agency) that biases visuospatial attention and responding to stimuli in the peripheral environment. Additionally, it documents how representing social targets in a script-coherent manner, i.e., in line with the convention for text direction, affects the attribution of important social traits.

This dissertation consists of three interrelated sections: a theoretical overview, the empirical research articles, and a general discussion. The theoretical overview is elaborated such that it gives a comprehensive frame of the models and conceptual assumptions that sustain the present dissertation. Its structure proceeds from a broad overview and focuses on specifics. It starts with a review of classical approaches to human cognition as embodied and contextually-dependent, to examinations of the culturally established use of space that grounds abstract categories and anchors the direction of social movement, and moves over to how asymmetric script direction to influences lateralized visuospatial attention via distinct types of cues and tasks. Finally, I summarize the aims of the current research project and introduce the seven empirical studies. This initial segment provides a chain of empirical evidence that supports the main tenets of the dissertation as well as were applicable, its contradictions.

The socially situated mind

Human cognition is dynamic and interactive but has not always been conceived as such. Traditional views contended that cognition is invariant, inert, and immune to contextual variations. These individual-oriented views of the human mind were particularly popular among intellectuals of the 19th-century German school of physiology and experimentalism who theorized cognition as inwards and subject-centered often neglecting environmental determinants. On the turn of the century, this intellectual tradition was challenged by scholars such as William James, George Mead, and John Dewey, who brought to the fore the impossibility of separating reasoning from experience, that is to say, men from nature, as men are not isolated from the world but instead contained in it (Dewey, 2008). This perspective draws from the American philosophy of pragmatism that rejected the proposition of the mind as a transcendent, static structure and chief source of knowledge, disconnected from participatory social experience. In pragmatic views, subject and object become intertwined; it is through joint communicative activity that individuals create a shared understanding of meaning within their social context which in turn informs individual behavior. The mind is not a closed-loop and thus cannot be reduced to the series of neurophysiological events that take place in the human organic structure. Only through the ongoing communicative process between agent and its social environment is the emergence of the mind made possible (Mead, 1934). The perspective of the human mind as contextually embedded surpassed American scholars and permeated the work of other prominent soviet psychologists in the 20th century such as Lev Vygotsky and Alexander Luria, who also postulated that the psyche is contingent upon culture and sociality. This shift in theoretical framing constitutes the foundations of what would later be coined as social cognition and has shaped the general principles that cut across many disciplines such as philosophy, sociology, and anthropology.

Indeed, the emergence of the ‘social mind’ is best represented by the unlimited combination of its several discrete elements which are nothing more than the multiplicity of dynamic relations possible between agent and world – i.e., their affordances (J. J. Gibson, 1979). The extent of the social mind rises above its single constituents much like “*language makes infinite use of finite media*” (von Humboldt, 1836/1971). The continuous mind-environment negotiation causes people to construe the world differently from what one would expect, based only on objective information and principles of formal logic. Instead, when reasoning about social information, people extrapolate from the given data. Thus, the cognitive output (attitudinal or behavioral) ascends the simple weighting and combining of available evidence rationally and judiciously (Higgins & Bargh, 1987; Kahneman & Tversky, 1973). The importance of context-dependency is deeply grounded in a basic tenet put forth by Gestalt theorists who emphasized that the specific sensory stimulus apprehended as a whole is qualitatively different from the sum of its composing elements (Wertheimer, 2010). Thus, cognition is socially distributed and maintained.

The social element in cognition is to be seen in how the representation of the social world is fundamentally linked to the actions performed by our bodies. As Semin and Cacioppo (2008) described:

"(…) *social cognition is best understood as grounded in (rather than abstracted from) perceptuomotor processes and intertwined with a wealth of interpersonal interaction and specialized for a distinctive class of stimuli. In the course of our lives, we are exposed to a vast range of stimuli, cars, buildings, trees, household objects, books, and, of course, other humans and an array of other life forms. Other human beings and their bodily movements constitute a distinctive class of stimuli, because the movements of other human beings can be mapped onto our own bodies* (p. 120)."

There is however a clear distinction between observing the movements of conspecifics and the movements of other species. Mapping the movements of conspecifics creates a common representational format for action that facilitates imitation and synchronization processes and enables empathy mechanisms (Carr et al., 2003). The intersection of the movements of others on ourselves allows for a sensory neural representation that makes intersubjectivity possible (Iacoboni, 2009). It is this mutually privileged access to a shared motor repertoire unique to humankind that permits the adaptive fine-tuning of our actions towards others. More than understanding of others it is about understanding with others (De Jaegher & Di Paolo, 2007). It is an ability to act appropriately in a particular situation based on a mutual tacit understanding that does not require the verbalization of reasons for actions (De Jaegher et al., 2010). Such a feeling of 'oneness' drives knowledge about human conspecifics which richness provides a common ground above any other form of interaction (Smith & Semin, 2007).

Cognition is for adaptive action and coordination and the successful interaction with other agents and the world (Semin & Smith, 2002). If not for the continuous co-regulation between human body architecture, behavior, and environmental resources (Semin & Cacioppo, 2009), little purpose would cognition serve. Thus, social cognition supersedes the viewpoint of the human mind as an isolated information-processing output unit operating without worldly feedback. Persons, events, subjects, and the relations they generate cannot be construed as mere passive objects, as this view would be far too simplistic to translate the dynamic reality of what constitutes being social. Therefore, fundamental cognitive processes such as perception, attention, memory, and learning are not detached from the environment and do not operate in the isolated body. Human experience is inherently dependent on the interplay between bodily structure and its recursive sensorimotor interactions with the social and physical settings (Landau et al., 2010). Thus, contrary to a Cartesian approach of mind and body as separate entities, psychological research today recognizes the functional value of human cognition that cannot be divorced from its sensorimotor bases nor perception and action (Damásio, 2011).

Consider, for instance, judgment and stereotype formation. Stereotypes were assumed to escape fleeting contextual influences because rigid mental dispositions were thought to be essential to cope with informational load (Hamilton & Trolier, 1986). An ample body of evidence has ousted the view of stereotypes as permanent mental representations independent of contextual forces. Stereotypes, like other mental models, are invariably tied to action because they serve practical and pragmatic concerns (Glenberg, 2008). Much like other heuristics, stereotypes are used to seek sufficient efficiency to meet the demands for rapid adaptation (S. T. Fiske, 1992). Their activation is not universal nor inevitable but rather adjusted online to the impending reality (Blair, 2002). There are numerous research examples of how stereotypes respond to situational pressures (affective appraisal of the situation, Schwarz, 2002; salience of typical of atypical exemplars, Smith, 1992; stereotype threat, Spencer et al., 2016).

The set of ‘core’ dimensions that underlie person impression, arguably labeled with distinct taxonomies across research traditions (competence vs. warmth, Cuddy et al., 2008; trustworthiness vs. dominance, Oosterhof & Todorov, 2008), has been proposed as universal precisely due to their functional basis in regulating behavioral and emotional response. These impressions are action-oriented because they offer useful cues about the abilities of others and their likely correlated behaviors (Mischel & Shoda, 1998). These cognitive shortcuts allow for “good enough judgments” (S. T. Fiske, 1992) that guide adequate and smooth social interaction when information and time are scarce. The underlying principle to these heuristics, however, is to be found on their functional value for efficient co-action instead of on a general account for social perceivers as lazy and error-inclined (Nisbett & Ross, 1980).

The environmental context and its physical features are key to comprehend just how malleable impression formation is. While the recollection of social exclusion induces reports of coldness (Zhong & Leonardelli, 2008), the physical sensation of warmth, induced by room temperature (Ijzerman & Semin, 2009) primes feelings of closeness with the target person and shapes language use. Actual physical proximity, i.e. being closer, translates into feelings of warmness (IJzerman & Semin, 2010) which perhaps explains why people recruit temperature-like terms (i.e., warm) when referring to loved ones with whom they wish interpersonal closeness (S. T. Fiske et al., 2007). These and other findings attest to the interdependence between physical structure and psychological processes as well as the remarkable capacity multisensory contextual cues have in shaping human functioning.

Naturally, the structural morphology of our bodies confines not only the nature and but the extent of the interactions we can engage in with the physical environment and its social occupants. Cognition is thus an embodied structure on which bodily states (i.e. postures, arm movements, gait, facial expressions) necessarily build. The central assumption to the embodiment account is that the representation of knowledge results from the partial simulations of sensory, motor, and introspective states such as emotions and beliefs activated during the concept's processing (Barsalou, 1999, 2008; Glenberg, 2008; Simmons & Barsalou, 2003; Zwaan, 2004). These corporeal states are partially stored when originally experienced, and later retrieved and sensorially re-enacted when knowledge of the event becomes relevant. Note that this does not mean that actual physical simulations need to be carried out, as suggested by William James' theory of ideomotor action (1890). These embodiments entail a wide range, which indeed may encompass full motor execution, but that are often circumscribed to simulations of bodily states in modality-specific brain areas (Barsalou et al., 2003). Embodied theories of cognition part ways from views that hold knowledge representation, that is human functioning, as amodal and the meaning of symbols as non-perceptual (Fodor, 1975; Kintsch, 1998). Quite the opposite, internal representations of the world are widely regarded as perceptually grounded and modality-based.

The significance of the social triggering of bodily responses can be seen in a study by Wells and Petty (1980). The authors established that performing bodily movements, namely vertical and horizontal head movements, influences agreement levels towards an editorial content (agreement was enhanced for nodding and pro-attitudinal content, and for shaking and counter-attitudinal content). Studies on approach-avoidance tendencies, a fundamental cornerstone of human development seen to foster survival, nicely illustrate the interface between body and cognition. For example, in a classic study participants' pull (approach) movements were facilitated for cards with pleasant words whilst unpleasant words fostered push (avoidance) movements (Solarz, 1960). The compatibility between affect and action on different couplings of push-pull or flexion-extension movements has been reported ever since (Cacioppo et al., 1993; Chen & Bargh, 1999; Paladino & Castelli, 2008; Rinck & Becker, 2007; Saraiva et al., 2013). In fact, the influence of bodily factors (i.e., body posture, for a review see Briñol & Petty, 2008) on message persuasion, attitudinal responses, and evaluations constitute a solid research tradition (Briñol et al., 2009; Briñol & Petty, 2003). Finally, a classic report on facial feedback, later replicated in different molds (Foroni & Semin, 2011), revealed that subtle bodily manipulations such as holding a pen between the teeth (forcing the smile) relative to between the lips (blocking the smile), produced funnier evaluations of cartoons (Strack et al., 1988).

Similarly, evidence is mounting that the comprehension of language takes place by the recruitment of the motor modality (Fischer & Zwaan, 2008). A common denominator to these studies is the use of perceptual and motor primes either congruent or incongruent with the features portrayed in a sentence. Congruency between motor primes (e.g., arm movement) and sentence features (e.g., dealing cards toward or away from the body) activates corresponding motor processes and thus faster judgments (Borreggine & Kaschak, 2006). Conversely, impaired performance on the same variables occurs for incongruent features of the prime and the sentence. Zwaan and Taylor (2006) demonstrated this language-based motor resonance by reporting that visualizing a rotating stimulus cross affected participants' manual rotation responses by a knob. The phenomenon of motor resonance traces back to the above-mentioned ideomotor principle of human actions, proposed by William James (1980) and its more recent derivatives (Greenwald, 1970; Hommel, 1996). This approach was revived by the discovery of mirror neurons in the macaque monkey which fire when the monkey observes an action of his own action repertoire being performed (e.g., grasping a food item, Gallese et al., 1996). Having a mental representation of the goal of an action (i.e., grasping, manipulating, placing) seems both necessary and sufficient for the comprehension of action sentences.

The same perceptual resonance can be found for perceptual primes. Kaschak and colleagues (2006) relied on a less common processing modality, audition, to show that auditory percepts implying motion found in nature affected the processing of concurrently presented action sentences. As for visual stimuli, mental imagery of animals and objects in a determining setting elicits faster responding when the shape of the object implied by the sentence (e.g., "egg on a refrigerator"/ "egg in a skillet") matched the drawing of the object participants were presented after ("whole uncooked egg"/ "fried egg") (Zwaan et al., 2002). Likewise, context seems to be sentential in lexical decision tasks on target words following prime sentences with ambiguous wording (Faust et al., 2002). The special value of this research is that not only people re-enact perceptual states during language comprehension, but they do so even when perceptual characteristics (such as shape) are not explicitly stated but only implied (Barsalou, 1999).

As only a few concrete concepts are seized through bodily experience (i.e., spatial orientation, containment; Lakoff & Johnson, 1980), the direct sensorimotor grounding approach encounters difficulties when explaining how we represent concepts, which unlike shape, weight, height, motion, temperature, color, we cannot access nor primarily encode via direct physical engagement (for a debate and alternative proposals see Dove, 2016; Mahon & Caramazza, 2008). Abstract concepts like happiness, morality, love, health, power, time, and affect are not only plentiful in everyday linguistic discourse but essential to the human social experience. Thus, such concepts must be structurally represented by some form of perceptual experience even if not one primarily linked to bodily motor actions. The conceptual metaphor theory (CMT, Lakoff & Johnson, 1980) offers a plausible answer to this puzzle.

Conceptual metaphor theory

Metaphoric expressions are common in natural language and are remarkably embedded in everyday life. They are uttered roughly six times per minute (Gibbs, 1992) and comprehended rather quickly and effortlessly (Glucksberg & Keysar, 1990). Metaphors are necessary communicative vehicles that allow the transfer of cognitive, emotional, and experiential characteristics contained in concepts devoid of physical grounding to others that afford tangible and sensory-based experiences (Ortony, 1975).

Aristotle (circa 335 BCE) was one of the first intellectuals to extensively discuss metaphor under rhetoric discourse, as a central tool that can prompt listeners to decipher how dissimilar things are alike. In Aristotle's view, metaphor by analogy is a fundamental linguistic mechanism through which learning, and persuasion operate, as learning easily is naturally pleasant to all people. There are profuse examples of pieces of literature where metaphor is key, from classic poetry epics such as Homer's Odyssey (e.g., "*great Odysseus melted into tears*") to 16th-century drama tragedies like Shakespeare's Romeo and Juliet (e.g., "*Juliet is the sun*"). In his book "*The Dehumanization of Art*" (1951), the Spanish philosopher José Ortega y Gasset furnishes a fascinating description of metaphor:

"*The metaphor is perhaps one of man's most fruitful potentialities. Its efficacy verges on magic, and it seems a tool for creation which God forgot inside one of His creatures when He made him. All our other faculties keep us within the realm of the real, of what is already there. The most we can do is to combine things or to break them up. The metaphor alone furnishes an escape; between the real things, it lets emerge imaginary reefs, a crop of floating islands. A strange thing, indeed, the existence in man of this mental activity which substitutes one thing for another (...)"* (pp. 33).

It is self-explanatory that, as a literary device, metaphors are figures of speech intended to embellish narratives and produce arresting and vivid representations in the minds of the audience. However, only the unobservant reader would reduce metaphors to mere ornamental purposes. The way metaphor meddles into colloquial discourse indicates that it is far more pervasive within language and that it is a central component of human cognition (e.g., "I am *stuck* on a job" (activities as containers); "Our relationship is *moving forward*" (affect as direction); “That was a *low* trick” (morality as space); “I *demolished* his argument” (argument as warfare)).

The ubiquity of metaphor in social discourse was perhaps best captured by social psychologist Solomon Asch (1958):

“*When we describe the workings of emotion, ideas, or trends of character, we almost invariably use terms that also denote properties and processes observable in the world of nature. Terms such as warm, hard, straight refer to properties of things and of persons. We say that a man thinks straight; that he faces a hard decision; that his feelings have cooled. We call persons deep and shallow, bright and full, colorful and colorless, rigid and elastic. Indeed, for the description of persons we draw upon the entire range of sensory modalities… the language of social experience and action reveals the same characteristic*.” (pp. 86)

The human mind comes equipped to discern, although not infallibly but insightfully enough, the abstract construction that is often underneath the concrete appearance conveyed by metaphors (Pinker, 2007). Metaphors not only amplify the expressive power of language but create a tacit understanding of seemingly literal meanings (Landau et al., 2010). But what significance do linguistic metaphors have for the understanding of people’s inner conceptions of the social world?

This question has been addressed by research on cognitive linguistics, namely by conceptual metaphor theory (Lakoff & Johnson, 1980, 1999). The underlying mechanism to conceptual metaphors is that people understand abstract concepts that lack direct physical experience by mapping them in terms of a small set of concrete yet dissimilar concepts that are easier to grasp. For the authors, the nature of all concepts which do not emerge out of physical experience must be metaphoric. The metaphor is therefore a tight set of correspondences (or *entailments*) between a *source* domain representing sensorial commonplace and familiar referents acquired via routine interactions with the physical world (e.g., up/down), and a *target* domain which represents abstract categories that are more difficult to comprehend (e.g., power, valence; Lakoff, 1993). For example, let’s take conventional expressions like “They *gravitated* to each other immediately” or “His whole life *revolves* around her”. Such expressions relate elements of love (the target domain) to elements of a physical force (electromagnetic, gravitational, etc.; the source domain). The metaphor relies on shared knowledge about a physical force of nature experienced by all to structure the closeness imposed by love, a much abstract concept which would otherwise be difficult to construe. One of the main criticisms advanced against the CMT is that the bulk of the evidence supporting metaphorical representation has purely linguistic bases (Murphy, 1996, 1997). As Murphy (1996) has pointed out, it is crucial to understand whether these metaphors simply reflect linguistic conventions or if they actually represent the processes that drive thinking. Cognitive scientists have thus strived to provide nonlinguistic evidence that can document direct links between metaphorical language and thought can be inferred.

Research in cognitive science has shown that linguistic metaphors can frame thought and behavior, although a variety of factors can make metaphors more or less influential in reasoning (e.g., prior knowledge of the target domain, Bosman, 1987; Johnson & Taylor, 1981). They can covertly shape how people attend to, remember, and process information (Landau et al., 2014; Mio et al., 1993). For example, in one study, Alan Turing was perceived as more of a genius when his ideas were described in terms of light bulbs rather than of seeds (Elmore & Luna-Lucero, 2016). Similarly, people prefer approaches based on social reform (versus enforcement) to deal with a city's crime problem when crime is described as a 'virus infesting the city' relative to a 'beast preying on the city' (Thibodeau & Boroditsky, 2011). Still, it can be argued that it is really lexical priming that underlies metaphoric usage (Patterson, 2016), since the word 'virus' spreads to lexical associates like 'threat' and 'cause' often employed to address reform-oriented approaches to crime-reduction (Thibodeau et al., 2017). Interestingly, and contrary to when people were metaphorically framed, when people were lexically primed with a list of synonyms for the words 'virus' or 'beast', suggestions to deal with the city's crime problem (i.e., reasonings on crime-reduction solutions) were similar across both word conditions (Thibodeau & Boroditsky, 2011). Although lexical priming cannot be ruled out as partially accounting for the effect of linguistic metaphor on reasoning, it seems that people reason in a way that is distinctive and consistent with the entailments of the metaphors.

Further, metaphorical reasoning can play an active role in language comprehension. A very revealing example is that there are at least two ways in which people map the progression of time onto space (Clark, 1973). In one, the entity moves relative to the observer who is the reference object: time moves past us (time-moving metaphor; "*The deadline is approaching*"/ "*Christmas is coming up*"). In the other, the observer moves towards the spatial entity: we move through time (ego-moving metaphor; "*We are approaching the deadline"/ "We are coming up on Christmas*") (Boroditsky, 2000; McGlone & Harding, 1998). In the absence of further evidence, one could deduce that these metaphorical representations are only language-deep and do not carry psychological consequences on the actual processing of time. A rather unusual study by Gentner and colleagues (2002) proved otherwise. Travelers at the Chicago O'Hare airport were approached by the experimenter and asked a question framed in the ego-moving metaphor ("*Is Boston ahead or behind us in time?"*) or in the time-moving form ("*Is it earlier or later in Boston than it is here?"*). After, the experimenter asked the critical question congruent with the ego-moving form ("*So, should I turn my watch forward or back?*). Response times measured through a stopwatch were shorter for consistently (ego-ego) rather than inconsistently primed questions (time-ego). These results highlight that two distinct conceptual schemas are involved in the way events in time are sequenced in people's minds, which is above and beyond mere speech.

Metaphors also have a discernable effect on attention and memory. The first has been the subject of limited experimental investigation relying on objective processing measures of attention (i.e., eye-tracking). In one such study, participants were exposed to sentences with fictive motion descriptions expressed in literal ("*The road is in the desert*") versus figurative language ("*The road goes through the desert*"). The authors showed that figurative language has a distinct and immediate effect on visual perception. For figurative speech only, eye movement data reveals that there was a more detailed inspection of the paths rather than the surrounding regions portrayed in visual scenes. Moreover, terrain information (*hilly* versus *flat*) was also incorporated in the representation of the metaphor and modulated looking behavior. Because hilly terrain would result in difficult and slower motion in real life, participants fixated longer at the path and more often along its length – i.e., evoked mental simulation of motion (Richardson & Matlock, 2007). It is remarkable that fictive, not actual, movement in the form of metaphor suffices to trigger sequenced eye movements that correspond to motion (Matlock et al., 2005). Even when metaphorical information is supplied in the auditory modality, eye-movements towards a blank screen tend to match the content of the narratives. Eye-movements are more pronounced along a specific axis of motion depending on the spatial movement implied by the stories. Participants made more vertical saccades when hearing about someone repelling down a canyon wall and more horizontal saccades when hearing about a train pull out of a station (Spivey & Geng, 2001).

As for memory, research has shown that metaphors and analogies create false memories (Perrott et al., 2005; Vendetti et al., 2014). Metaphorical mappings further affect the retrieval of episodic descriptions. Children's recall of book passages was facilitated when these contained metaphors rather than their literal paraphrases (Pearson et al., 1981). Interestingly, making participants aware of the conceptual metaphoric relation of the items presented in an episodic memory task leads to poorer recall performance than when such instructions are not provided (Katz & Law, 2010). This suggests that the activation of conceptual metaphors is effortless and that bringing conscience upon such mappings may be counterproductive and disruptive to episodic recollection.

Indeed, because they are so entrenched in everyday language and reasoning, these metaphors are primarily unconscious and automatic (Lakoff, 2012). Primary abstract-concrete links are conceptualized in childhood through experiential co-occurrence (e.g., feeling happy and having an upright posture (affect-verticality); higher body temperature when being held by a caregiver (warmth-closeness). Despite the existence of some evolutionary proclivities (Cohen & Leung, 2009), the neural correlates resulting from these links are thought to be reinforced by the multiple iterations with the concrete domains. Such situations become abstracted only later in life and eventually become co-expressed in metaphors (e.g., "*happy is up*") (Lakoff & Johnson, 1999). The question however is not yet settled whether it is through empirical co-occurrences that primary metaphors are formed. For example, the primary metaphor "*bad is stinky*", cannot be present in early infancy since the representation of disgust emerges somewhere after eight years of age (Rozin & Fallon, 1987). Thus, the correlation between evaluative and olfactory experience (like the smell of sweat or feces) is not forged by primary experiences as children will put anything in their mouths. Instead, disgust reactions are learned and are extremely flexible even within individual organisms, that vary disgust patterns according to the external circumstances (Toronchuk & Ellis, 2007).

It is important to note that the CMT offers limited predictions regarding how metaphors respond to variations in context, a constituent feature of situated social cognition (Barsalou, 1999). The CMT has a strong focus on how invariable and universal physical referents are determinant to think and talk about concepts that are abstract by nature. Metaphors are persistent rather than transient and one of their hallmarks is that they establish a one-way asymmetrical relation whereby properties of the source domain feed the target domain but not the other way around (e.g., "Jobs are jails" is logical but 'Jails are jobs' is nonsensical, Glucksberg et al., 1997). Social development is consistent with the idea of asymmetric perceptual-conceptual associations since sensorimotor achievements in childhood occur before the emergence of abstract thought (Piaget & Inhelder, 1969, for converging evidence see Meier & Robinson, 2004, study 3). However, the theory does not elaborate much further on how the mental mappings established between concrete and abstract concepts are activated nor which aspects of the source domain would be critical for reasoning about the target domain as a function of the context's locally salient information. This shortcoming is particularly relevant for research on social inferences which are highly susceptible to situational primes. Additionally, and as mentioned above, the set of experiential concepts learned through bodily knowledge is small. These include fundamental spatial relations (e.g. horizontality/verticality), physical ontological concepts (e.g. entity, container), and basic experiences or actions (e.g. movement) (Boroditsky, 2000).

So far, I have provided an overview of how metaphors unintendedly pervade thought by shaping social inferences, language processing, attention, and memory. In the next part, I will focus on studies investigating the metaphorical structuring of several abstract concepts, with a particular focus on those perceptually structured by spatial relations.

Space: A common metric to represent abstract categories

The previous section has provided evidence that systematizes metaphors as being above and beyond mere figurative speech bearing no relation to how people come to conceptualize and talk about abstract domains. Instead, metaphors encompass specific mental mappings that bring in information from the experiential basis of the concrete source concept (e.g., space) to the understanding of the abstract target concept (e.g., time). When these links are activated, metaphors provide scaffolds to reason about abstract domains.

Dyadic classification seems to be a particularly convenient way to culturally represent opposing concepts as "*all known cultures – primitive as well as advanced – use dual classifications and polar opposites*" (p. 23) (Laponce, 1983). One abstract concept which has generated abounding research is brightness/darkness. The metaphor brightness-good darkness-bad is a so-called primary metaphor, that is, arising through experiential correlation (Ortiz, 2011; Winter, 2014). Darkness is early linked to negativity since most children experience fear of the dark (King et al., 1997). Darkness and negative events are correlated in nature as we are simply more vulnerable in the dark and more likely to stumble, trip, and hurt ourselves. This basic metaphor is widely observed in folklore, mythology, and religion. For example, Dante conceives of God as a light blindingly bright while the Dantean Hades lives underground in a place of gloomy darkness. Historically, epochs of oppression and stagnation are referred to as dark (i.e., the Dark Ages) whilst times of progress and intellectual liberty are remembered as bright (i.e., the Age of Enlightenment). This metaphor comes across clearly still today in different forms of media and pop culture (Forceville & Renckens, 2013) and thus appears unaffected by cultural variation (Adams & Osgood, 1973) and immune to changes wrought by time (Osborn, 1967). Brightness/light typically symbolizes positive concepts like health, optimism, purity, and motivates expressions like "*having a bright idea*" or "*the bright side of* *life*”. On the other hand, linguistic expressions like “*she has a dark personality*” or “*these are dark times*” are used to convey negative concepts like evil, danger, and death.

Attesting the association between brightness and valence, Banerjee and colleagues (2012) reported that participants recalling an unethical versus an ethical behavior perceived a room as darker and expressed more desire for light-emitting products (e.g., flashlight) (although Brandt et al., 2014 failed to replicate these results). This association finds further support in the work of Meier and colleagues (2004) who reported faster evaluation of positive words (e.g., ‘hero’) when these matched the font color congruent with the metaphor (i.e., white). However, the positive-white association emerges only in contrast with the negative-black; it is the polar opposition of black and white categories that makes the contrast salient and hence structures the opposition in the valence dimension (Lakens et al., 2012).

Another distinct yet interrelated abstract concept is morality. Similar effects to those obtained by Meier and colleagues (2004) with brightness were reported with morality-related concepts (Sherman & Clore, 2009). Morality is commonly expressed in terms of cleanness, a surrogate for moral purification (e.g., “*having a clean conscience”*). The association between bodily purity and moral purity is a focal element of religion (i.e., “*clean hands make a pure heart*”) and deeply rooted in religious ceremonies (i.e., baptism). But do people actually embody the concept of morality by preferring activities related to cleaning?

Zhong and Liljenquist (2006) have provided evidence that threatening one’s moral purity increases the mental accessibility of cleansing-related words. Participants were asked to recall either a good or a bad deed from their past. After, they engaged in a word completion task by converting word fragments that could form a cleansing-related or unrelated word into meaningful words (e.g., wish/wash; step/soap). They observed that more cleansing words were generated by participants who recalled a moral trespass (e.g., adultery). Finally, after writing about a past moral transgression, participants were allowed to either clean their hands with a wipe or not. They were later approached by the experimenter to help a graduate student by participating in another experiment. Participants who had not cleaned their hands, i.e., who had not been given the opportunity to ‘wash away’ the unethical deed and restore a pure conscience, were more prone to engage in a good deed (helping someone). The authors thus established what they called the ‘Macbeth effect’ – i.e., a threat to moral integrity that cannot be absolved otherwise induces the need for physical cleansing. Similar but more refined evidence comes from Lee and Schwarz (2010) who demonstrated that the need for cleansing is specific to the body part used to perform the mischief: participants preferred mouthwash when asked to lie verbally, and hand wipes when asked to type a lie.

As contended by the CMT, spatial orientation is one of the few concrete concepts acquired via bodily experience able to structure abstract categories (Lakoff & Johnson, 1980). Vertical and horizontal properties of space can be deployed to ground different abstract concepts. For instance, the representation of affect-related concepts relies on metaphors alluding to the vertical dimension (e.g., "*I am feeling up*"; "*You are in high spirits today*"; "*I have never felt so low*"). Three studies by Meier and Robinson (2004) demonstrate that affect has an automatic physical bias. Participants produced faster word classifications when the location of the words on the screen was congruent with the metaphor 'good is up/bad is down'. That is, positive words (e.g., generous) were classified more rapidly when presented at the top of the screen and negative words (e.g., hostile) on the bottom of the screen. Similar results were obtained with adjectives denoting positive and negative emotions confirming the metaphor 'happy is up' (Santiago et al., 2011). Similarly, spatial memory is affected by upward and downward movements. Casasanto and Dijkstra (2010) reported that people retrieve positive or negative autobiographical memories faster when the direction in which they were asked to move marbles was congruent with the valence of the memory. Crawford and colleagues (2006) extended these findings to emotionally evocative image primes. Participants viewed images of positive/negative content in various locations then reproduced each image's location from memory. Affective responses influenced spatial representation from memory as the placement of the images was biased in line with the stimulus valence (positive images biased upwards; negative images bias downwards). In fact, because verticality enters our experience in multiple and distinct ways, up-down physical coordinates shape many different abstract concepts although, in reality, they all derive from the metaphor 'good is up' and 'bad is down' (e.g., more is up, control is up, power is up, divine is up, moral is up) (Lakoff & Johnson, 1980).

Concepts of power/powerlessness have also been found to be expressed in terms of upper and downward vertical positions, respectively. The representation of power through verticality is observed across cultures, as can be seen in architectural manifestations across ages ranging from pyramids, to gothic cathedrals, to modern skyscrapers. Interestingly, Meier and Robinson (2006) established a correlation between depressive symptoms and the preference for attending lower regions of physical space, which is backed up by research showing a link between slumped body posture and feelings of helplessness, decreased persistence, and failure (Riskind, 1984). In contrast, those who perceive themselves as more powerful and dominant tend to be faster when responding to probes in the vertical dimension than more submissive individuals (Moeller et al., 2008). This is not surprising since perceptions of power and dominance are strongly intertwined (Dunbar, 2004). Other studies have confirmed the use of vertical space to represent dominant versus submissive personality traits (Robinson et al., 2008) and gender stereotypes (Lamer & Weisbuch, 2019). The overlap between vertical positioning and dominance inferences is further observable under the context of sexual attractiveness and mate selection. Evolutionary theories of mate desirability (Buss, 1994) argue that mate selection is carried out to successfully produce healthy offspring. To this end, women prefer mates who have access to resources and higher social status (i.e., powerful) while men consider women who are faithful and subordinate (i.e., powerless) more desirable as these traits increase the chances of the man being the father of the female's offspring. Incidentally, these personality preferences are drawn from physical features, since males favor shorter females as females favor taller males (Shepperd & Strathman, 1989). Building upon this argument, Meier and Dionne (2009) speculated and found that vertical position is an implicit cue for power used to formulate attractiveness judgments: females rated male photos as more attractive when appearing in higher locations, and males rated female photos as more attractive when presented in lower locations.

A series of studies by Schubert (2005) confirms that social power is symbolically structured by vertical spatial positions, i.e., 'power equals up'. In one study, participants had to decide as quickly as possible which of the two group labels presented simultaneously on the screen (e.g., master-servant; professor-student) was the most powerful. Critically, the group labels were presented above each other, either with the powerful one on the top or on the bottom. Vertical differences in the representation of power did influence speed and accuracy of power judgments so that finding the powerful group was facilitated when it was presented on the top rather than on the bottom. This mental association affects motor decisions but has further downstream consequences in judgment. In another study, Schubert (2005) has used powerful and powerless animals instead to directly measure judgments of respect, a proxy for power, through a question. However, this more subtle manipulation of power failed to fully reproduce effects obtained with stereotypical powerful and powerless groups of humans. Although showing pictures of animals at a different place on the screen subtly changed power judgments, this effect was observable for powerful animals only which may indicate that the power-verticality link is not that straightforward. In any case, this evidence converges on the Fiske's (2004) hypothesis that displays of spatial information affect perceptions of the leaders' power, as authority ranking is primarily represented through vertical distance and differences in size. This possibility was examined by Giessner and Schubert (2007) who reported that increasing the vertical, but not the horizontal, length of a line in an organization chart between manager and subordinates instigated higher power judgments of the leader.

Findings on power judgments can easily be extended to the communication about the divine, a highly abstract concept interwoven with power that borrows from the same perceptual domain of verticality (e.g., "*Glory to God in the Highest*"). As research addressed above has demonstrated, light-dark metaphors are grounded in vertical space and people consistently employ them to structure discourse on divinity in both Christian and non-Christian religions (Haidt & Algoe, 2004). The significance of upper space as well as upper-orientated behaviors typically accompanies religious practice (e.g., the priest holds up the consecrated Host) and spiritual experiences (e.g., transcendence states are often described as leaving the body and gravitating in a higher space). The concept of Hell is also widely shared and negative religious creatures are often portrayed as populating lower regions of space (i.e., snakes move on the ground, but angels move above it). Meier and colleagues (2007) showed that verticality aids in the representation of the divine. Across two studies, they established that both divinity-related concepts and divinity-related images are encoded faster and remembered more accurately when their location on the screen was metaphor-consistent. Further, accessing divinity-related cognitions led participants to rate pictures of strangers as more likely to believe in God when appearing in a high versus low position. Chasteen and colleagues (2010) went one step further by demonstrating that exposure to divine concepts modulates visual attention by triggering upward and downward shifts of attention following God- and Devil-related words, respectively. Moreover, the bias is not modulated by the degree to which people believe in the divine as results did not vary as a function of the participants' religious endorsement. This evidence nicely illustrates the extent to which the default framework to reason about the divine is spatial in nature and pervades cognitive processing well beyond belief.

On the other hand, the perceptual experience of the horizontal dimension is used to make sense of time. Some elements of time are extractable from our experience with the world. For instance, time is physically marked by diverse devices that establish apparent spatial patterns (e.g., sundials, clocks, hourglasses). Additionally, social experience dictates that time has a unidirectional flow, that is, events are temporarily bounded and irreversible ("you cannot step into the same river twice" as put by Heraclitus), and we cannot go back in time. Although time is a fairly universal construct, its representation is not, since there are clear cultural differences in metaphors to do with time (Kövecses, 2005). Intricate subtleties on the representation of time are observed across cultures. For example, Mandarin speakers rely on vertical and horizontal terms to describe the passing of time whilst European language users employ horizontal terms exclusively (Boroditsky, 2001). Specifically, vertical spatial primes induce faster truth judgments to sentences such as 'March comes earlier than April' for Mandarin speakers, but the same judgments were facilitated for English speakers when primed horizontally. It is thus not a matter of how people talk about time but how the construal of time is shaped by language. Despite assuming multiple conceptualizations across cultures, spatial terms used to talk about time always reflect its one-dimensional and unidirectional nature (e.g., 'left-right', 'front-back', 'ahead-behind'; Clark, 1973). What is constant is that the grounding of time has the body as a focal, reference point. A report by Boroditsky and Gabi (2010) clearly illustrates this premise. The authors report data from a remote aboriginal community that arranges time in a strikingly different way: according to the cardinal directions (east to west). This means that time is conceived as flowing both from left-to-right (or right-to-left) when one is facing south (or north), and toward or away from the body when facing east or west, respectively. Notwithstanding, all these remarkably different representations have the body as a frame of reference. Even when asked to contemplate naturalistic clips or pictures in hindsight, westerners organize events sequentially from left to right in mental space (Santiago et al., 2010). Indeed, people also gesture from left to right when describing events unfolding in time (Núñez & Sweetser, 2006).

The correspondences between space and time are commonly observed in language particularly in the use of spatial metaphors. Events are described such that 'the past is *behind* us' or 'we are *ahead* of schedule'. Such tight link evidences that westerners conceive time as evolving along a horizontal continuum that unfolds from the left space, which is used to represent past events, to the right space which represents future events. These expressions are not mere linguistic regularities but rather unveil how the domain of time is structured and reasoned about. These metaphors evoke off-line spatial schemas needed to provide relational information that organizes events along a timeline (Boroditsky, 2000) and are in all likelihood shaped by writing direction (Nachshon, 1985). However, because relying only on informal discourse would be insufficient to claim that metaphors underlie thought representations, sizable research has been conducted to show that humans structure time flow on a spatially oriented mental timeline.

One effect commonly reported is the response compatibility between time-related stimuli and spatial response codes (Ishihara et al., 2008). For example, Vallesi and colleagues (2011) reported that the estimation of the temporal duration of an event (a cross on the screen) was modulated by the use of left and right hands to respond. Responses were faster in conditions compatible with the metaphor, that is left-hand response generated shorter duration judgments, and right-hand response generated longer duration judgments. Similar results were obtained by Conson and colleagues (2008) in a task judging the duration and order of auditory tones.

Participants responded by pressing the left or right key to judge whether the first or second spatially uninformative tone in a pair was shorter or longer. The authors reported an interaction between duration, order, and space, whereby responses were facilitated not only when the shorter tone was presented first but also when participants responded with the left hand, and vice-versa. Casasanto and Boroditsky (2008) have further demonstrated that judgments on duration and distance serve as proxies for time as they are equally biased by irrelevant spatial information. All this evidence is particularly interesting because it emerges from fundamentally nonlinguistic tasks, thus revealing that metaphors operate on a deeper level.

Conceptual congruency tasks have also revealed that the activation of future and past-related words triggers congruent attention shifts and primes motor responses to the right and left space, respectively (Ouellet, Santiago, Funes, et al., 2010). Importantly, these results rise above stimulus-compatibility effects (Fitts & Seeger, 1953) as the authors orthogonally controlled for word location and temporal meaning. Weger and Pratt (2008) have also shown that past- and future-related words facilitate not only manual responses but also modulate visual attention. Other researchers have demonstrated similar results with both left-right and back-front spatial frames (Santiago et al., 2007; Torralbo et al., 2006).

Ouellet and colleagues (2010) extended this evidence by testing the asymmetrical structuring of time in the auditory modality. Participants had to discriminate past or future verbs and adverbs presented to the left and right ears (orthogonally controlled) by pressing left or right response keys. Notably, two groups of participants differing in the directionality of their orthographic system were recruited: Spanish (left-to-right language script) and Hebrew (right-to-left language script). Critically, Spanish participants performed better when past words were responded with the left hand and future words were responded with the right hand. The opposite, although more modest, pattern was observed for Hebrew participants whose language script maps time reversely, from right to left. There is one additional important contribution to these studies: past and future judgments were given based on auditory stimulus only, thus ruling out spatial biases induced by the directional act of reading a word prime. The results thus show that the mapping of time a) is not modality dependent, b) is above the relative left-right spatial positioning of the effectors; and c) is shaped by reading and writing scanning habits and is by no means universal. Lakens and colleagues (2011) devised an auditory disambiguation task to demonstrate that future-related words when presented binaurally and equally loud to both ears, were judged to be louder when presented on the right channel. In the same set of experiments, participants revealed biased placing of the past and future terms to the left and right midpoint of a horizontal line, reflecting not only metaphor use but also that temporal terms are not ruled by a dichotomous left-right categorization but instead show a semantic gradation (i.e., the word 'past' is further to the left than the word 'yesterday'). Thus, the mapping of time in space seems to converge across modalities.

The processing of numerical information also shares similar cognitive mechanisms. Magnitudes are processed according to a spatially-defined reference system. The well-documented SNARC effect (spatial numerical association of response codes, Fischer et al., 2003; Ito & Hatta, 2004) proposes that responses to large numbers are facilitated on the right space and responses to small numbers on the left space. The effect emerges in tasks requiring explicit comparison (e.g., x is smaller than y) and tasks were magnitude is irrelevant (e.g., parity judgments) (Dehaene et al., 1993). Notably, this effect is not restricted to quantitative order sequences as it also emerges with the ordering of months of the year, days of the week, and letters of the alphabet (Gevers et al., 2003). The processing of time and number share resources by drawing upon common magnitude mechanisms. Evidence for the linking of time and number rests on dual-task experiments: secondary visual tasks disrupt performance on a primary temporal estimation task due to the demands placed on the subject, but only a secondary task of mental arithmetic (which requires the use of numerals) is completely impaired by a temporal task (Casini & Macar, 1997). This evidence substantiates the coupling between magnitudes and space along a left-right analogical timeline.

Spatial opposites of the left-right horizontal axis are also used to make sense of the political landscape. When we think and talk of politics, we do so by associating left/right political ideologies to the left and right spatial poles on horizontal space. The 'left-wing' and 'right-wing' terminology is frequently employed to describe the range of liberal and conservative political orientations. The coining of these terms is thought to date back to 1789 in reference to the physical seating arrangements of members in the French National Assembly (Arian & Shamir, 1983). The usage of spatial coordinates to structure the political spectrum has then become a shorthand to describe the progressive 'left' and the traditionalist 'right'. Thus, the lateral political referents seem to have been born from haphazard historical rather than organic sources. Laponce's work (1983) offers a fascinating alternate non-arbitrary account for the symbol 'right' having become charged with political significance. He poses that in most societies, 'right' has consistently been correlated with moral virtue and instrumental competence. This moral polarity finds its foundations on the asymmetries of the body and the higher prevalence of right-handed individuals (Hertz, 2013). Indeed, the predominance of right-handedness has been attributed to biological substrates of the left-hemisphere physiological superiority for language and articulated speech (although the link between handedness and brain asymmetry has been strongly contested, G. B. D. Scott, 1955). The preference for the right hand exceeds biological factors and is eventually further manifested in the associations of the words left and right in several languages. French (gauche/droit) and Italian (sinistra/destra) are fine exemplars; left means awkward, inept, and ill-omened, while right encompasses positive connotations of proper, correct, and just. According to Laponce, this is how right comes to signify dominance and legitimacy in political discourse: the anatomical disposition favoring right-hand skill together with societal and religious projection of the right space as eminent and superior. For the author, the left political terminology is simply defined in terms of its opposing relation to the right. Nevertheless, irrespective of its origins, the metaphorical way of communicating the opposing ends of political ideologies has pervasively entered the vernacular and remained ever since both in language and culture (Goodsell, 1988).

To test this premise, Oppenheimer and Trail (2010) spatially primed participants by physically orienting them toward the left and right in a chair, by having them squeeze a hand-grip with the left or right hand, or by instructing them to click on an object more often on the right or left space. After, participants filled out a political attitudes' measures ('*To what extent do you agree with Democrats/Republicans on political issues?*'). Critically, when spatially primed to the left (right), participants tended to agree more with democrat (republican) policies. It should be noted, however, that the manipulation led to substantial change in people oriented towards the left compared to the right. The authors propose that this may be because most people are right-handed and therefore chronically oriented toward the right. Indeed, spatial metaphors affect left- and right-handers differently because of enduring exposure (Casasanto, 2009). Nevertheless, political affiliation did not play a role in reported political attitudes indicating that at least ambivalent political attitudes may be swayed by spatial priming.

In three distinct tasks (semantic categorization, lexical categorization, color discrimination), van Elk and colleagues (2010) have shown that responses to a political acronym were faster when the location of the hand button pressed (left or right) was consistent with the ideology conveyed by the political party. An additional go/no-go semantic categorization task of Dutch political parties revealed that decisions were facilitated when the acronyms were presented on the side of the screen that corresponded to their political orientation. Because participants were required to respond with the right hand only, the authors conclude that the results are not driven by the overlap between instances of left and right and the positioning of the effectors. Instead, the processing of political acronyms activated their associated spatial mappings. A further interesting nuance to this research is that it shows that people conceive the political orientation of parties with their own political preference as a baseline anchor. Reaction time effects reflected the participants' political positioning such that, for instance, people favoring left-wing policies represent politically-right parties as being at the far end of the political spectrum when in fact these parties may not be governed by extreme ideologies.

Other research relying on semantic stimuli provides converging results for the horizontal mapping of politics. Farias and colleagues (2013) attested that political terms of left and right (e.g., 'revolution'/ 'consumerism') are biasedly distributed on a horizontal line. Participants placed socialism-referent words more to the left of the line's midpoint and conservatism-referent words more to the right. Interestingly, in absolute distance from the scale's midpoint, socialism words were skewed more to the left than conservatism words were to the right hinting at the underlying influence of the habitual left-to-right writing direction of participants (Suitner & Maass, 2016). Like what Lakens and colleagues (2011) had observed with time-related words, the authors tested the overlap between semantic 'intensity' of the word and its visual representation. Political words semantically judged as more socialist (e.g., 'communism') were placed further left than those deemed less socialist (e.g., 'demonstration'), which confirms that representation of political terms is not reducible to a dichotomous left-right space. The same horizontal anchoring of words was reported in the auditory modality as participants more often disambiguated equally loud words as being louder to the ear corresponding to the political connotation of the word. These findings are important because they reveal that the spatial grounding of politics is multimodal and that these groundings share a substantial overlap across different representational tasks. A later set of experiments by the same authors (2016) examined whether the visual and auditory spatial grounding of political categories is driven by stimulus-compatibility effects, an account proposed to explain conceptual cueing effects (Proctor & Cho, 2006). That is, if the obtained spatial groundings are a result of the dimensional (i.e., physical) match/mismatch between stimulus and response codes. Key, hand, and label used to respond were orthogonally controlled to the horizontal axis. The results replicate previous facilitation effects for couplings of left-socialism and right-conservatism thus establishing that the spatial grounding of politics is independent of stimulus-response compatibility.

Mills and colleagues (2015) further demonstrated that political stimuli lacking direct association with physical space (i.e., pictures of Democrats and Republicans presented centrally at the screen) triggered faster target detection (experiment 1) and attention shifts (experiment 2) to the visual field consistent with the ideology of the politician. Importantly, the political ideology induced a biased choice of gaze (participants were asked to freely direct their gaze to the left or right) even when the politicians' photos lacked a direct link with physical space. Lastly, polarity benefits arising from the overlap between concept and target location are improbable since participants were unlikely to have perceived the figures as a binary variable (left/right).

Overall, evidence on the spatial grounding of politics is relatively sparse and not as well documented as that on instances of time, number or magnitude. Nevertheless, it reveals crucial aspects that distinguish politics from other abstract concepts mapping onto the same horizontal dimension. For one, and as discussed earlier, the usage of spatial nomenclature on politics is fairly recent - at least relative to a concept as ubiquitous as time (i.e., 'as old as time'). For the same reason, its derivative terms are not as deeply engrained in colloquial discourse, hence the exposure to such terms is less frequent in a relative way. Second, the category of politics is permeable to a number of individual moderators which are difficult to control and may introduce additional noise (e.g., political knowledge, engagement, and affiliation). Third, political concepts are subjected to contextual fluctuations which time or number are exempted from. Politics are dynamic and consequently so is the meaning of its correlated concepts; time is invariant. Finally, out of all the categories reviewed here, politics is perhaps the one lacking primary spatial links and the most remotely associated with space. For these intricacies, political categories are a prime candidate for the study of conceptual metaphors and its implications. Should the spatial grounding of politics prove systematic effects across different stimuli, tasks, and modalities, one can uncover just how deeply embedded conceptual metaphors are in cognitive processing.

This part has provided an overview of research typifying how the perceptual experience of space can be recruited to reason about abstract concepts and articulate them. Admittedly, the processing of metaphorical language operates in the individual, yet the individual does not operate in the vacuum. Therefore, cultural and environmental exposure must impose additional pressures on spatial groundings. The way we read and write, namely the script direction of our native language, has been consistently reported to produce asymmetries that shape these mappings as well as many other cognitive processes beyond them (Suitner & Maass, 2016). These scanning practices become habitualized to such an extent that they produce a subtle, unidirectional influence on how human agency is envisaged. Alike other abstract concepts covered here, agency also maps onto the horizontal dimension. It is tightly connected to how we move and perceive motion in space and thus a fundamental dimension sustaining embodied cognition. In what follows, a brief preamble introduces research on the origins of human agency from the standpoint of distinct disciplines. Further, I elaborate on how horizontal asymmetries derived from writing routines modulate agency perception – the central focus of the present dissertation.

The case for agency

Agency is an ill-defined concept that has long been at the center stage of humanities' disciplines of anthropology, sociology, and philosophy. The term itself has maintained a certain elusive vagueness across literature as doers are often endowed with additional, albeit correlated, qualities such as motivation, dominance, ambition, intentionality, purposiveness, freedom, and so forth (see Hitlin & Elder, 2007 for a discussion). Therefore, social thinkers have struggled to distinguish agency as an analytical category in its own right.

Many present-day assumptions on human agency stem from the early Enlightenment teleological philosophers who came to conceptualize the individual as a free agent capable of rational choices for himself in the process of social engagement (Lukes, 1973). For instance, John Locke's works were preponderant in theorizing free agency by unshackling social thought from the institutionalized power of tradition. The binding religious authority of the times then came to a close with the rejection of innate ideas and the praise of free autonomous inquiry and individual experience. Locke's ideas (as well as those of his contemporary empiricists) on the tacit social contract negotiated between the individual and the authority served as the breeding ground for the theories of a subsequent line of scholars who contended humans as free to both consent to and withdraw from such social agreement. These views have then sustained a newfound conception of agency, one where the individual is a situated actor responding to changing environments, capable of shaping his own circumstances. The ascendancy of the individual will and the concept of intentional action underlie what are today Western belief systems and accounts of freedom and progress (in fact, Lockean ideas of inalienable natural rights were adopted by American revolutionaries and are patent in the U.S. Declaration of Independence).

Thus, agency as a decisive element for the successful social experience within which human beings impress themselves has been subjected to scrutiny ever since. For example, the French philosopher Henri Bergson (2001) called it *élan vital*, or vital impetus, a driving force sustaining human orthogenesis, creative impulse and progress. For Bergson, this spontaneous organic drive, expressed by our bodily apparatus through motility, is paramount for the subject's negotiations with the external world. The concept borrows from Arthur Schopenhauer's *will to live*, the constant yet insatiable individual urge to perpetually satisfy successive goals. It should not be confused with the basic psychological drive for self-preservation in response to life-threatening circumstances; the *will* entails a much more fundamental human necessity - a blind striving for existence that pumps human motion and without which Nature could not exist.

An opposing, Kant-inspired, account is put forth by Talcott Parsons in "*The Structure of Social Action*" (1968) who rejected agency as a crude primitive drive that is directionless and aimless. Parsons captured agency in terms of *effort*, a force that is structurally functional and utilitarian and targeted towards a concrete end. Further, James Coleman, a neo-Parsonian in many respects, stated that *"actions are caused by their (anticipated) consequences"* (1986, p. 1312) denoting that this guided means-ends impulse to act is abstracted from the unfolding situations the actor systematically faces. That is, human agentic orientation would be invariant and not susceptible to temporal change. Now, this construal of agency was alien to pragmatist thinkers like George Mead who placed agency within a temporal framework and the actor as contextually embedded. Pragmatist views on agency stress that action should not be comprehended in terms of a pursuit of predetermined ends immune to environmental pressures. Instead, because time is a flow of co-occurring nested events, human action should be situated in multiple relational contexts in time. Thus, the individual draws from habitus and structured routinized practices to deliberate and act upon emergent situations (Joas, 1996).

From a psychological stance, Bandura (2006) has contended that humans evolved into sentient agentic species able to volitionally act to alter the course of events. This refers to what Bandura termed *intentionality* – humans are not mere onlookers of their behavior but rather proactive self-organizing and self-regulating authors of their life paths. Notably, plasticity of behavior and agentic competence are the hallmark of human nature (Dobzhansky, 1972). Although fortuitous intersects constitute a substantial slice of events in life, individuals can actively steer their way by forming intentions, strategizing to achieve specific goals, and associating with others who have the resources and knowledge they lack. Moreover, we do not have direct control over most of the conditions that affect our endeavors because they involve other participating actors. Thus, absolute individual agency can never really be attained as humans have to commit to shared intentions, compromise to distinct plans of action, and accommodate others' interests if they wish to secure desired outcomes (Bratman, 1999). The balancing act of conjoint action via pooled resources is what sustains human social experience and is key to shape collective efficacy (Bandura, 1995). Individuals are never truly independent agents, but neither is their behavior entirely enforced by situational coerces. Instead, biological constraints, societal rule structures, individual, and intrapersonal behavior inform each other in a dynamic interplay to guide human agency (Burns & Dietz, 1992). Selfhood is thus a fine-tuning of the multiple combinations emerging from hard environmental determinism and the individual capacity for freedom and choice. Further, the sense of agency, i.e. the acknowledgment of one's ability to master one's environment, is what contributes to the subjective phenomenon of self-consciousness (Gallagher, 2000).

Another core property to human agency, one that nicely converges with Mead's philosophical account of agency as temporarily extended, is forethought (Bandura, 1989). Forethought regulates agentic behavior and is a distinctive human characteristic. Motivations that guide efforts to reach prospective outcomes rely heavily on the ability to anticipate possibilities based on causal relations formed throughout life. Infants are born without any sense of personal agency but are quick to establish action causation through systematic iterations and the observation of contingent occurrences (Mandler, 1992) - a vicarious agency, if you will. They learn that certain objects remain motionless unless manipulated. Later, children develop into directly experiencing that their actions produce effects. They receive proprioceptive feedback from their own activities, extending the sense of general action causality to personal causality and fostering the notion of an agentic self (Bandura, 2006). These continuous transactions with the environment establish probabilistic outcomes and inform the individual about the likely consequences of certain actions. Such recurrent patterns are imperative to the later aptitude for forethought. Humans are thus able to anticipate future events and visualize goals by bringing their representations into the present moment to ignite current actions. The experience of agency, the everyday feeling of being in control, arises from the prediction (based on stored sensory inputs) and monitoring (based on the consequences) of our own motor commands (Haggard & Tsakiris, 2009).

The broad take-home message is that the self as a mere conduit for environmental forces that foster action is a truncated image of human agency. People are intentional cognizers, not devoid of purpose, yet the extension of their ability to self-generate is admittedly bounded by the social and cultural milieu. Evolutionary calls for new advantageous adaptations, as well as the emergence of language and abstract reasoning, ushered human beings into agentic action through which they transcend their environmental dictates. I believe this section served as a prelude to introducing human agency and has conveyed the gist of the story: agency is a poorly articulated concept across disciplines which has been a matter of scholarly debate over centuries. However fascinating, I shall not elaborate further on the nature and locus of human agency as it regrettably falls outside the scope of the present dissertation. The next part will cover human agentic capacity in terms of physical movement. Specifically, the section will be furnished with ample research asserting that culture, via scanning practices, exerts an influence on how people imagine and represent social movement.

Mapping agency in space: Spatial agency bias

According to the Spatial Agency Bias model (SAB hereinafter), human agency is envisaged in the direction in which we read and write (Suitner & Maass, 2016). Native writing systems, which vary widely across the globe, seem to affect how agency is mentally conceived and consequentially how it translates in terms of preferential human movement. Historically, the spatial arrangement of symbols falls into either vertical (e.g., top-bottom) or horizontal (e.g., left-right) layouts. Routinized practices of reading and writing have then inevitably generalized to other unrelated activities, establishing a scanning habit that becomes the convention for exploring space in any given culture. Even certain acculturated behaviors (e.g., gestures) are themselves a form of agency, one that paradoxically arises from the experiences afforded by movement (Noland, 2010). The phenomenon for biased motion perception and representation seems to emerge from two joint process, namely the habitual scanning of texts and the undergoing of writing activities, and the standard syntactical structure of active sentences that determines subject-object order and is present in 83% of all languages (Dryer, 2011). The spatial agency bias is therefore a byproduct of a visual-motor component and a linguistic component (Suitner & Maass, 2016). Thus, it is only logical to surmise that modes of writing affect human reasoning. But how does the direction of different writing systems affect performance in tasks that go beyond reading and writing activities?

People rely on the spatial information provided by the horizontal ocular and motor movement of reading and writing practices to conceive agency. Agency, or *the capacity to act autonomously in a given environment* (p. 248, Suitner & Maass, 2016), is thus represented according to the script direction of one’s native language - evolving rightward (i.e., left-to-right) in ‘Western’ languages, and leftward (i.e., right-to-left) in languages such as Arabic, Hebrew, Farsi, and Urdu. The spatial information grounding agency is used both for mental imagery (encoding) and for representation and interpretation of the concept (decoding). For instance, when asked to pictorially represent sentences describing an action (e.g., ‘the girl pushes the boy’), Italian participants were more likely to place the agent of the action to the left of the recipient. In contrast, Arab-speaking participants systematically positioned the agent to the right of the recipient, with the action evolving leftward (Maass, Suitner, & Nadhmi, 2014; Maass & Russo, 2003). In addition, the rightward vector (an arrow pointing right) is overwhelmingly preferred by western participants to symbolically represent agency when compared to other spatially oriented vectors (leftward, upward, and downward arrows) (Suitner et al., 2017). Interestingly, the opposing arrow (pointing left) was deemed by participants as more appropriate to represent communal traits.

A great portion of our lives is spent in reading and, to an increasingly lesser extent, handwriting activities. Since infancy, children are instigated to engage in directional mock activities of reading and writing (Nuerk et al., 2015). There is an early predisposition that precedes formal education to display spatial asymmetries that favor the trajectory of the language children are socialized into. Many exercises for preverbal children rely on verbal instruction (e.g., 'color object x first and object y last') which primes children to ordering items in space according to spatial conventions (i.e., the first object to be colored corresponds to the location at which writing starts). Children learn word-by-word pointing in observing directional storybook reading and understand how a story progresses (Dooley, 2010) hence extracting the directionality of their native writing system and applying it, for instance, on counting (Göbel et al., 2018). Additionally, measuring devices to which children are early familiarized with (e.g., rulers, tape measures) instantiate the directionality of concepts like number line. Several studies have shown that Western preschoolers display a preference for left-to-right ordinal sequences (de Hevia et al., 2014), digit sequences (Opfer & Furlong, 2011), and object counting (Shaki et al., 2012).

Space-number associations, which are tightly linked to agency perception as I will elaborate ahead, are already observable in pre-literate children even when magnitude is task-irrelevant and there is no explicit necessity for spatial-numerical decisions (Hoffmann et al., 2013). De Hevia and Spelke (2009) had children bisecting a horizontal line flanked by either symbolic (Arabic figures) and non-symbolic numerical information (an array of dots). They have shown that 7-year-olds (who can recognize Arabic digits) displayed spatial-numerical interaction for non-symbolic flankers by systematically misplacing the midpoint of the horizontal line accordingly. Remarkably, they displayed a general leftward bias which coincides with the preferred scanning habits observed when children start learning how to read and write (Fagard & Dahmen, 2003). Younger preverbal children revealed the exact same biased bisection placement when presented with non-symbolical dots suggesting that children make use of directional intuitions acquired by experience (Opfer & Thompson, 2006) and that formal education is not paramount to the emergence of number-space correlates. A further important inference that can be drawn from these studies is that information conveyed by Arabic symbols is not yet habitualized at the age of 7 and is not processed rapidly and effectively enough to be modulated by spatial biases (Girelli et al., 2000). Indeed, studies have shown that younger children on the verge of formal education and uneducated adults alike have broad conceptions of magnitude scale, however, these are in clear contrast with the well-established number/space linear mapping accomplished only through schooling and manifested across adulthood (Siegler & Opfer, 2003). This means that part of these mappings can be acquired by primary cultural exposure and experience and remaining rests on structured directional activities provided by formal literacy.

The ubiquitous nature of the spatial bias, with varying maturation throughout the several stages of human development, renders it difficult to pinpoint how and when it was acquired. For example, in a cross-linguistic study with German and Israeli preschoolers, Dobel and colleagues (2007), failed to observe a directional bias in the representation of action sentences with animate agent and recipients (e.g., 'the mother gives the boy a ball' or 'The boy gets a ball from his mother'). The authors found the placement of agent and recipient by the children to be random. In contrast, the agency bias in spatial representation of semantic relations emerged for adults: Germans showed a left-sided preference for agents whilst Hebrew-speaking participants preferred the right positioning. The authors conclude that there is malleability in pre-literate children's capacity to represent spatial relations and that consolidated exposure to writing systems is wholly responsible for the directional bias in movement representation. Similar (lack of) evidence for preschool, but not school-age children, in drawing of side view objects is reported by Kebbe and Vinter (2012). This premise converges with that of other authors arguing that young infants are sensitive to pick up on spatial relations represented in languages other than their own (i.e., Korean versus English, Hespos & Spelke, 2004). In the same vein, Patro and colleagues (2016) have demonstrated that spatial directionality in preschool children (a SNARC-like effect) is modulated by training in a previous visuomotor task (moving a frog across a pond from left-to-right or right-to-left).

Distinct proposals have been put forth as the source of spatial asymmetries in the perception of agency and human movement. Biological accounts have highlighted the universal properties of brain architecture as responsible for driving a left-to-right preference for spatial organization. Indeed, the dominance of the right hemisphere for visuospatial tasks is thought to cause the leftward asymmetrical anchoring observed in the exploration of visual space (Brooks et al., 2014). Hemisphere specialization-based hypotheses for visuospatial processing has often been proposed as underlying the favoring of left hemispace in allocation of attention, frequently manifested in exercises of line bisection (for a review see Jewell & McCourt, 2000). The phenomenon, termed as pseudoneglect (Bowers & Heilman, 1980), is best observed in neurologically normal individuals who tend to misbisect the horizontal plane erring to the left of the line's midpoint. This attentional asymmetry in visual line bisection has its counterpart in haptic modalities as well (Bradshaw et al., 1983). The pure neurobiological account for the lateralization of spatial attention finds support in studies reporting the same bias in pecking behavior in non-human species (birds, Diekamp et al., 2005; chickens, Regolin, 2006). However, although the pseudoneglect phenomenon has and continues to generate a great buzz, structural brain asymmetries are no longer taken as the sole driving force behind attentional asymmetries. This assumption has emerged as a result of conflicting research demonstrating that the overestimation of the left side of space observed in pseudoneglect is susceptible to modulation by a series of stimulus properties (e.g., line length, azimuthal line position, line aspect ratio; McCourt & Jewell, 1999) and even abolishable by manipulation of body posture or head orientation (Bradshaw et al., 1985).

Abundant research has come to highlight cultural factors, often overlooked to the detriment of biological ones, as pivotal contributors for spatial and motor biases. Specifically, written script, reading direction, as well as cultural experience, have all been suggested to create regularities capable of shaping spatial preferences (Kazandjian & Chokron, 2008). A universal culture of cognition shared by all has thus been gradually abandoned by scholars as this account alone failed to explain mirror performance in many cognitive tasks reported with right-to-left readers. For instance, there is mounting evidence that line bisection tasks are culture-dependent and subject to modulation via language script (Chokron et al., 1998; Chokron & Imbert, 1993; Kazandjian et al., 2010). Reversals of the left bias are found in right-to-left native speakers in plentiful other tasks such as chimeric face evaluation (Vaid & Singh, 1989), aesthetic preference and judgment (Chokron & De Agostini, 2000), free-hand drawing (Vaid et al., 2002), thematic role assignment (Chatterjee et al., 1995), entertainment (Maass et al., 2007), temporal preferences in schedule representation (Tversky et al., 1991), apparent motion (Tse & Cavanagh, 2000), inhibition of return (Spalek & Hammad, 2005), number and timeline representation (Santiago et al., 2007), gender categorization (Suitner et al., 2017), group stereotyping (Maass et al., 2009), and memory (Bettinsoli et al., 2019), among others.

Research has provided evidence that the left-anchoring tendency for human attention is, at the very least, attenuated by opposing writing systems (Rosenich et al., 2020). Although the use of spatial information is reversed in leftward native speakers for a range of distinct tasks, it is not uncommon to encounter weaker results in these populations. Apart from the influence of innate right hemispheric dominance that directly counters right-to-left scanning trajectory, a second possibility for the weaker manifestation of the bias in leftward cultures is that these populations are generally familiar with left-to-right scripts (Suitner & Maass, 2016). For example, many Arabic-speaking countries formally teach French as a second language, a remnant of earlier colonization periods. Hebrew-speakers are often exposed to the English language as well as other bidirectional experiences, making such a population highly 'westernized'. In contrast, rightward-speaking individuals are hardly introduced to contrary scripts in media, entertainment, advertisement, pop culture, etc., unless they voluntarily seek such information (e.g., learning a leftward language). Also, bidirectional readers show insignificant to no lateralization in task performance (Kermani et al., 2018; Rinaldi et al., 2014b). Bilinguals from opposing script directions are exposed to contradictory directional habits which are difficult to reconcile. These habits will enter into competition, leading to a weaker lateral bias than that exhibited by people with one consistent script directionality (Nachshon, 1985). A stronger lateralization in the internal representation of action should occur as congruent experiences accumulate but should weaken with the continuous exposure to conflicting scripts. Likewise, Maass and Russo (2003) concluded that spatial biases in representing human interactions assessed in Italy-based Arabic-speaking participants was a direct function of the number of years spent in Italy. A recent strand in the literature has suggested that bidirectional readers can flexibly switch between conflicting acquired scripts adjusting spatial strategies according to the demands of the task at hand (Afsari et al., 2016; Nazir et al., 2004). In any case, all these studies suggest that spatial asymmetries are acculturated, unknowingly so, based on the degree of exposure to the script opposing one's mother-tongue.

In sum, an interactive, rather than mutually exclusive, account of attentional biases accommodating genetic predispositions as well as routines enforced by habit and culture has gained support over the years (Bulf et al., 2017; Chokron, 2002; Kazandjian & Chokron, 2008). Admittedly, hemispheric specialization is encoded in our genetics and is at the core of visuospatial asymmetries; culture arises as an additional layer. It superimposes on biological biases either reinforcing (in the case of left-to-right readers) or otherwise reducing/overriding them (in the case of right-to-left readers and bidirectional readers). Hence, the dynamic interplay between biological and cultural contributors results in spatial asymmetries that are weighed differently across individuals and are, in all likelihood, dependent on the exposure to different scripts.

To address the conceptual leap of how script direction translates into a general asymmetrical visual scanning that goes beyond reading and writing activities, Suitner and Maass (2016) contend that repeated exposure to the dominant directional preferences in a society leads to a 'schema for action'. The schema for action is a general pattern for inferring, representing, and expecting motion. Accordingly, any dynamic action, conveyed by moving objects and humans alike, is engraved in people's imagery as unfolding in a script-coherent direction. The bias is perpetuated through socialization. In everyday life, people engage in all sorts of directional behaviors not necessarily linked to reading and writing habits but nevertheless consistent with them. This means that spatial biases begin with literacy experience and impositions of orthography (and possibly earlier directional experiences, Patro, Nuerk, et al., 2016) but are preserved through continuous contact with culturally promoted spatial displays leading to habitualization and biased mental model construction (e.g., organization of bookshelves, comic strips, billboards, graphs, Websites; Hernandez et al., 2017; Maass, Suitner, & Deconchy, 2014; Román et al., 2018). The result is a generalized scanning trajectory that becomes the standard for exploring our social environment, therefore biasing how information is encoded and retrieved in subtle yet automatic ways. Attention and memory are conditioned by such regularities that are no longer built exclusively on reading and writing practices but pervade human reasoning. Ultimately, the development of the schema for action scales from conceiving single actions following written script to representing the abstract concept of agency in the same manner, a fundamental social dimension.

Space is for communication: Aesthetic and social inferencing of agency

As introduced before, asymmetric scanning habits serve as a compass to infer dynamism and activity and have a preponderant role in governing people's expectations about these characteristics in others. The SAB finds its underpinnings in motor and visual experience. Action and space are assumed to interweave in a loop whereby directional motor activity reinforces the established spatial mapping of agency, and the simulation of the motor system (for example, when people are presented with stimuli that convey motion) promotes the use of biased representations of agency (Suitner & Maass, 2016). It is a circular feedback mechanism between body and mind that consolidates biased mental representations of actions. It follows that the SAB is more likely to become salient when presented with dynamic relative to static images given that the first triggers motoric simulations to a greater extent. For instance, Friedrich and Elias (2016) investigated the role of (implied) motion in the aesthetic appreciation of images. Besides reporting opposite preference for mirror images differing in directionality (left-to-right and right-to-left), they observed that participants from opposing writing systems all preferred dynamic images and videos (mobile objects) over static images and videos (landscapes). Román and colleagues (2013) went one step further and demonstrated that in drawing static scenes (e.g., 'the table is between the lamp and the TV') the placement of the lateral objects was marked by the participants' native script much more so than by the degree of practice with that script.

Many representational and social inferencing processes as well as attentional-cognitive ones are permeated by asymmetric regularities mimicking script direction. For instance, at first sight, the production of aesthetic judgments appears to be a process rather remote from reading and writing habits. It is thus remarkable to verify that lateral biases derived from literacy routines exert a substantial impact on aesthetic preferences. Flath and colleagues (2019) had participants with left-to-right and right-to-left native language direction rating mirror-reversed clips portraying models wearing dresses on a runway. Rightward readers reported a higher preference for dresses moving in a left-to-right direction, however, no significant preference in directionality was observed for leftward readers. The authors conclude that the result obtained for right-to-left participants supports a combination of both hemispheric dominance and cultural immersion in different writing systems. The biologically-grounded distribution of attention to the left hemispace is speculated to work against the cultural leftward bias of right-to-left participants, thus resulting in negligible results. Indeed, Friedrich and colleagues (2014) report similar conclusions for still and motion pictures in left-to-right speakers only. In general, participants from western language scripts evaluate right-oriented motion and right-facing figures as more aesthetically pleasing than their mirrored counterparts (Vaid, 2011). Cross-linguistic studies report the opposite bias for right-to-left native participants in aesthetic appreciation (Heath et al., 2005; Nachson et al., 1999). For example, Padakannaya and colleagues (2002) tested the directional exploration of artwork and further recall capacity in children speaking Arabic (leftward script), Kannada (rightward script), or both Urdu (leftward) and English (rightward). The authors relied on flashcards with 2, 3, 4, or 5 picture arrays of common objects and asked children to name the objects in which order they liked. Naming order as well as the direction of recall (from right-to-left or left-to-right) was a function of the children's reading habits. Importantly, for children with conflicting scripts (English and Urdu), the strength of these effects decreased with the number of school years in English.

Concurrent evidence is observable in the entertainment domain. Maass and colleagues (2007) analyzed people's perception of directional human action. Italian- and Arabic-speaking participants saw a clip of a football goal and a fistfight unfolding both in left-to-right and right-to-left trajectories. The goal was perceived as faster and more spectacular, and the fighting scene as more violent and harmful when it matched the participants' habitual writing script. These findings nicely illustrate that subtle spatial preferences for motion exist and operate even in fundamentally non-linguistic domains. A likely candidate for the exaggerated perceptions of directional movement is perceptual fluency, that is, participants would perceive whatever action as more forceful when it evolves in the 'correct' direction (in line with their scanning habits). This is because stimuli that evolve like other known habitual movements are processed with greater ease that is misattributed to the stimuli itself and results in increased judgments (Maass, Suitner, & Deconchy, 2014). Observing motion in the dominant cultural direction may produce what has been termed a subjective experience of fit, which intensifies evaluations and outcomes (Higgins, 1997). Concurrently, such exacerbation in movement perception may be owing to people's capacity to incorporate physical principles (e.g., momentum) to project and anticipate motion much further than the bit of trajectory they are shown, albeit with minor displacement (representational momentum, Hubbard, 2005).

Directional information is integrated when judging human action, but people further utilize spatial location to communicate properties of agency and its correlated characteristics (i.e., active, dominant, industrious, powerful, assertive; Abele et al., 2008; Hitlin & Elder, 2007). In addressing the symbolic association between agency and the rightward direction, Suitner and colleagues (2017) demonstrated that opposing spatial layouts are used to portray women and men (left and right space, respectively) and that positioning of the actors is used to infer and process social information. They report clear space-gender associations with a) rightward male targets being attributed more agentic qualities than (rightward) female targets, and b) male (relative to female) photos being considered more authentic when represented in rightward (versus leftward) profile, presumably because men are considered more agentic and agency is revealed in left-right coordinates (Chatterjee, 2002). This evidence converges with previous studies proposing statistical regularities in spatial arrangements of gender in Western portrait paintings, with females represented overwhelmingly facing leftward (Suitner & McManus, 2011).

Decades of research on stereotype content have shown that communal traits (e.g., softness, warmth) are indeed stereotypically reserved for women as opposed to agentic traits (e.g., competence, assertiveness) which are at the core of the stereotypical male (Abele, 2003; S. T. Fiske et al., 2007). Therefore, males, but not females, are represented along the vector used to convey agency and which mirrors the motor activity of writing (Suitner & Maass, 2016). Communion (and other female-correlated traits) has no particular motoric anchor, it emerges only in opposition to agency hence it is a byproduct of the spatial agency bias and not a bias in its own right. This is confirmed by a negative correlation between opposing spatial trajectories envisaged for agency and communion (rightward and leftward, respectively; Suitner et al., 2017).

The phenomena are relevant for advertising contexts as well; visuals function within a convention-based system and consumers hold certain expectations regarding the spatial arrangements of visual elements (L. M. Scott, 1994). In a recent report, Monahan and Romero (2020) show that brand trust increases when the ad features an object (i.e., car, boat, runner) implying motion from left-to-right, rather than right-to-left. Confidence in the brand is mediated by the sense of 'feeling right' that arises from the match between the ad motion and the script western costumers are accustomed to. More interesting for current concerns is that brand trust was moderated by gender associations. The effect was accentuated for left-right ad motion only when it advertised a product strongly associated with masculine properties (e.g., a truck) but not with less masculine properties (e.g., a minivan). This evidence is important in that it documents that people can extract gender-space associations and produce evaluations accordingly even when the featured target is a product merely resembling male/female features and not necessarily a person. Importantly, Suitner and colleagues (2017) were pioneers in showing that agentic space-gender associations are permeable to change through counterstereotypical conditioning. After learning a new, and unfamiliar, association pattern (females – rightward direction), participants reported reduced sexism levels. Casasanto and Bottini (2014) had already proposed a similar mechanism. They observed that promoting the learning of a novel embodied process - mirror reading – led people to develop new links between space and the abstract concept of time. Therefore, spatial conventions should not be taken as deterministic but as malleable and susceptible to reversal by training (Rosenich et al., 2020); spatial coordinates are a two-edged sword since they can be used as a tool both to perpetuate and change stereotypic gender roles.

Associations between agency and space are not confined to individual agents (Maass & Russo, 2003) but further extend to the stereotypical placement of groups. In one study, Italian speakers over-proportionally placed agentic groups (men, young people) to the left of groups assigned with less agentic qualities (women, old people) (Maass et al., 2009). The placement of groups was reversed for the Arabic-speaking sample, following an order that parallels with right-to-left unfolding scripts. Endorsement of the bias emerged only for participants with marked traditional gender roles and failed to emerge for atypical agentic exemplars (e.g., Homer Simpson). Thus, in people's mental imagery, groups (as well as single individuals) occupy script-coherent positions. These spatial placements are by no means arbitrary and communicate to perceivers agentic differences between groups that reinforce the established social structure. Group value is yet another piece of information that spatial placements can transmit. Lamer and colleagues (2020) investigated whether the spatial distribution of different categories of magnet images (kitten/lizard; minivan/sports car; ballerina/football player) was a function of ingroup bias and/or stereotypical placement bias. They observed an advantageous positioning of objects according to the gender of participants, that is, objects pertaining to the participant's gender were placed higher and more to the left than those pertaining to the opposite gender. They concluded that under some settings (for example, when traditional gender roles are made salient), the gender identity/ingroup bias prevails over the agency bias in spatial placements.

The primacy of the left positioning of men is observed in name order preferences (Hegarty et al., 2011), graph displays (Hegarty et al., 2010), and spatial arrangement of gender couples (Carnaghi et al., 2014). Importantly, the stereotype-based account of agency occurs only when targets meet the participants' stereotypical expectations. This means that privileged leftward placement of men is observed for gender-conforming heterosexual couples whereby males are depicted as providers having high-profile jobs and females as housewives (Hegarty et al., 2010). Similarly, female-male order of couples occurs only when males and females are nonconforming members of their categories, i.e., females with high-status and males with low-status jobs. In fact, the bias was eradicated for pairs with equally low-status jobs and hence where no agentic character could be designated (Carnaghi et al., 2014).

The studies reviewed in this section have illustrated, with distinct nuances, how spatial coordinates of left and right are recruited to shape overall artistic and aesthetic preferences and to diffuse stereotypes that maintain the societal status quo. However, interpersonal and group relations pertain to a secondary stage of human functioning, the SAB acts on a much primary level. Regularities imposed by script are ingrained in mental functioning to such extent that basic processes like attention are liable to contamination. The following part is dedicated to the impact culturally acquired asymmetries have on a central nonlinguistic cognitive process: the deployment of spatial attention.

Spatial attention: Essentially primed through script direction?

People are primed to start scanning space where writing/reading begins (upper left corner in western orthographies, unless told otherwise) with the eyes moving and attention proceeding in a script-coherent direction. As the reader comprehends how points progress in space, space-motion mapping becomes activated and a natural correlation is formed between the two (Casasanto & Bottini, 2014). Although it is possible to dissociate eye-movements from visual attention (take, for instance, covert versus overt attention), eyes generally follow attention allocation. The likely explanation is that such oculomotor behavior is beneficial for improved individual performance and sensory acquisition of environmental changes (Abrams et al., 1990). In sum, eye movements are tied to the organization of information (Griffin, 2004) which typically observes the same trajectory as written script. The visual attention system deploys spatial attention opportunistically; it takes advantage of environmental invariants to allocate attention more efficiently.

Attention is biased in a manner consistent with the physical property of momentum. Once attention is set in motion, it would be costly and counterproductive to go against its trajectory and return to its initial location (attentional momentum, Pratt et al., 1999). With attentional momentum, individuals can track objects more easily by anticipating their likely next location. Therefore, attention is contingent to object motion. Thus, individuals always favor the deployment of attention to novel rather than already scanned locations which, adaptively speaking, decreases the chances of predation (inhibition of return, Posner et al., 1985). Spalek and Hammad (2004) reported that a directional bias exists in inhibition of return; a larger effect (higher impediment of returning to an already attended location) was observed when the initial cue was presented on the left (generating left-to-right attention movement) relative to the right of the fixation cross. The same authors (2005) later observed the contrary effect in inhibition of return for an Egyptian sample from where it is possible to surmise that the bias in attention shifts is caused by the consistent habit of text-reading. An early report by Pollatsek and colleagues (1981) is consistent with this interpretation. By monitoring participants' eye movements, they observed that the visual attentional field, or perceptual span, was deployed asymmetrically to the left when native Israelis read a Hebrew text and to the right when they read an English text. The phenomenon of representational momentum (Freyd & Finke, 1984), a slight displacement in the final position of a moving object, is also influenced by the direction of object motion. People systematically miscalculate an object's final position as being further along the path to a greater extent when the object moves along the left-right vector (Halpern & Kelly, 1993). The same error is observed when objects move from top to bottom (Hubbard, 1990), that is resembling gravity forces, which reinforces that attention allocation is not innately biased but subject to environmental regularities.

Where people attend first is dependent on their native writing system. Initial saccades to the left space are observed in free visual exploration in left-to-right readers (Ossandón et al., 2014). For example, Palanica and Itier (2011) reported an asymmetry in eye movement allocation in detecting direct versus averted gaze in an array of full body figures, favoring response to targets in the far-left visual field (but not the right). The authors attributed the trend for leftward bias in initial visual exploration to right hemispheric dominance, neglecting any cultural influences. A primacy for left-anchoring attention was also observed in comparative judgments of linear order for Western participants, but a right-anchoring tendency emerged for Iranian participants (von Hecker et al., 2016). Eviatar (1995) has further shown that when stimuli are presented bilaterally (items presented simultaneously in the two hemifields), English speakers struggle to disregard the leftmost irrelevant information, the first element their attention is guided towards. Ignoring an irrelevant letter is hardest for Hebrew speakers when it is shown in the right space. Consequently, performance on the locations opposite to where scanning begins (right side for English; left side for Hebrew) is compromised. Even in the face of ambiguous stimuli (e.g., diamond shapes) resembling apparent motion, American viewers exhibit a bias modeled after the acquired reading habit (Morikawa & McBeath, 1992). Another piece of evidence that people scrutinize visual materials from left-to-right comes from a study by De Dreu and colleagues (2009). European participants were more likely to reach an impasse at negotiations when a critical item was placed on the left of a pay-off table. The obstacle item became prominent in the negotiation much earlier than when it was placed on the table's right-hand column.

To disentangle possible confounds between written script and other directional aspects of culture, Bergen and Lau (2012) tested speakers of English (left-to-right), Taiwanese (top-to-bottom starting on the right), and Mainland Chinese (currently left-to-right but with a long history of top-to-bottom). Taiwanese and Chinese would then differ in their current writing system but would share vast cultural spatial values. In testing diverse non-linguistic aspects of cognition, they reported an effect on visual attention whereby English and Chinese participants composed sentences with the element presented on the left-hand side of a paper first followed by the element on the right. A preference for beginning sentences with the element on the right of the paper was observed for Taiwanese. Participants' attention system seems to have scanned the presented images along the same vector as that of their script; the first element they chose to include corresponds to the position they first gazed at. As a consequence of biased visual attention, memory is also affected by script direction, with better recall occurring for items positioned where writing starts (Bettinsoli et al., 2019).

Spatial cueing: Gaze, faces, words, and more

Several successful attempts have shown that exposure to concepts grounding on the left-right movement continuum, not necessarily agency but agency-derived (e.g., time, numbers, politics, etc.), trigger attention shifts congruent with the concept's spatial mapping. To assess the phenomena, variations of spatial cueing tasks are typically used (Posner, 1980; Posner & Cohen, 1984). The phenomenon is your robust congruency effect whereas performance is increased when cue and target coincide in their location, it is hampered when they do not. However, methodologies too often rely on behavioral measures alone such as reaction time, which merely hint at the underlying mechanism to asymmetric orientation of attention via covert shifts of attention (orienting attention without an overt eye-movement response). Less frequently are process measures like eye-tracking included, the only true measure of visuospatial attention. A study by Masson and colleagues (2018) extended previous results (Masson & Pesenti, 2014) by combining both measures and showing that subtractions and additions in mental arithmetic generate leftward and rightward attention and detection biases (but see Glaser & Knops, 2020 for results in addition problems only). The reverse also holds: inducing attention to lateralized distractors (in left or right space) interferes with arithmetic in problem-solving (subtractions or additions, respectively) (Masson & Pesenti, 2016). These studies show that the direction of attentional shifts is driven by the semantical assessment of the operator (plus or minus) as well as the magnitude of the operation's product (large or small digits) which are associated with left-right space in number line representation (Pinhas et al., 2014). Importantly, because arithmetic problems were presented auditorily, and hence results cannot be explained by directional reading processes, spontaneous eye-movements must reflect semantic left-right imagery of the concepts.

Spatial attentional cues have assumed many forms. Among the most popular are visual cues and particularly, face and gaze. Abundant research has shown that face and gaze cues consistently guide spatial attention and facilitate the detection of impending stimulus congruent with the location implied by the cue (for a comprehensive review see Frischen et al., 2007). Integrated perceptions of gaze, head, and body position cues are imperative for decoding other's intentions, and making decisions concerning social attention direction (Hietanen, 2002; Langton, 2000) and personality judgments (Bayliss & Tipper, 2006). Gaze direction is one of the most relied upon basic social cues (Hood et al., 1998) that is picked up since early infancy (Farroni et al., 2004). In fact, primates are equipped with specific cells in the superior temporal sulcus (STS) to respond selectively to the direction of body, head, and gaze perceived in others (Perrett et al., 1990).

The capacity for joint attention, that is for gaze-following behavior, seems to come from innate neural modules (an Eye Direction Detector, Baron-Cohen, 1995) and is a critical precursor to understanding the mental states of other individuals. Connections between the STS and the intraparietal sulcus (IPS), an area implicated in spatial processing and attention orienting (Nobre et al., 1997) process information about gaze-direction and trigger joint attention behavior in the corresponding direction. For example, faces averted laterally, a clear directional stimulus, produce stronger responses in the IPS than faces gazing front (Hoffman & Haxby, 2000). The eyes are ecologically valid stimuli for both human and non-human animals, capable of signaling a wide range of key negative information like environmental threat and peril (Mendelson et al., 1982; Argyle & Cook, 1976) and positive information like approach behavior and romantic interest (Mason et al., 2005). An abrupt change in another's gaze is taken as a sign for environmental change that one should attend to, regardless of its valence (Byrne & Whiten, 1991). Therefore, rapid and efficient gaze detection is vital for the individual's chances of survival and offspring production.

Numerous studies have documented that perceiving face and gaze direction automatically elicits attention shifts. For example, Friesen and Kingstone (1998) exposed participants to directional gaze shifts (left, right, straight ahead) presented at fixation and observed that peripheral target detection, localization, and identification was facilitated because it elicited a corresponding shift of attention in the observer. What is more, participants were told that the gaze direction did not predict the upcoming target location, thus it was in the participants' best interest to disregard the cue for improved performance. The fact that they could not reveals that gaze cueing involves reflexive, or automatic, covert attention (no eye-movement measures were recorded to claim overt attention) (Jonides, 1981). Three additional arguments are in favor of reflexive attention (outside participant's voluntary control) are that: a) the effect emerged very rapidly, between 105 and 300 ms of stimulus onset asynchrony (SOA), a signature of reflexive attention orienting (Cheal & Lyon, 1991); b) benefits at cued location (cued-target RT < neutral RT) were produced without costs (uncued-target RT = neutral RT) (Posner & Snyder, 1975); and c) cueing effects persisted for a short time course (1,000-msec cue-target SOA) (Müller & Rabbitt, 1989). These effects combined rule out the possibility that participant's made use of any strategies to respond. Further, this was the first study to observe automatic attention shifts with cues presented at a central location (but many have followed, B. S. Gibson & Bryant, 2005; Langton & Bruce, 2000). Thus far, that role was reserved to abrupt onsets (e.g., changes in luminance) occurring at peripheral locations that are capable of instantly grabbing attention and which refer to target locations more directly. Conversely, centrally presented cues (e.g., arrows, and other directional symbols) were thought to elicit voluntary attention only; they provided no direct spatial cue-target link and thus participants would have to interpret the meaning of the cue to orient attention (see Klein et al., 1992 for a review). Driver and colleagues (1999) later replicated Friesen and Kingstone's (1998) results with an additional manipulation that instructed participants that the target was four times more likely to appear at the uncued location. Still, participants were unable to suppress automatic shifts of attention towards the gazed location, at least at short SOA's (300 ms).

The advent of eye-tracking afforded more accurate measures of attention orienting responses. For example, even when participants are instructed to fixate on the center of the screen during cue exposure period, left and right averted gaze cues triggered corresponding spontaneous saccades before target onset (Mansfield et al., 2003), a result which did not emerge for non-social cues (i.e. arrows). This suggests that gaze prompts a simulated oculomotor behavior in the observer that cannot be contained. This evidences that mirror activations occur for the oculomotor system (as they occur for motor domains as well, e.g., reaching and grasping actions, Grafton et al., 1996) because cortical regions are recruited during observation of eye movements (Grosbras et al., 2005). Other eye-movement studies have extensively reported that participants' oculomotor movements tend to follow the direction of the gaze of diverse actors (Itier et al., 2007; Zwickel & Melissa, 2010). Ricciardelli and colleagues (2002) went as far as instructing participants what saccade was to be made to potential targets simultaneously located to the left and right of fixation. Target performance decreased when a distractor averted face incongruent (relative to congruent) with saccade instruction was presented centrally. This effect was milder when the distractors were pointing arrows.

Indeed, faces and gaze are a distinct type of cue due to their preponderance in social communication. A growing number of investigations have substantiated the uniqueness of gaze cues, reporting a clear differentiation in attention shifts between faces and arrows (but see Galfano et al., 2012; Tipples, 2008 for contradicting evidence). For example, memory accuracy is improved when information is cued by gaze but not arrows (Gregory & Jackson, 2017). Marotta and colleagues (2018) have also shown that eye-gaze and arrows used as targets in a typical interference task produce opposite effects: while arrows elicit the typical stroop effect (slower reaction times) when cue-target information is incongruent, gazes accelerate responding behavior. Evidently, a logical explanation to such differences is that gaze is a biologically and socially relevant stimulus that humans are equipped to detect and that cannot be escaped. It takes primacy over other kinds of symbolic cues, although humans can reflexively follow other directional signals to a lesser degree.

Of importance to the present dissertation are studies employing words as directional cues for the deployment of spatial attention. It is well established that the spatial positioning of words interacts with lexical processing so much so that people have an evolutionary propensity to remember locations in the environment where relevant stimuli typically occur (spatial registration hypothesis, Coslett, 1999). This means that the symbolic representation of a certain object (word) is associated with the sensory properties of that object including its common positioning in space. For example, word pairs like attic-basement or sky-ground are more often judged as semantically related when its presentation mimics their natural spatial arrangement (e.g., attic in upper space, basement in lower space) (Zwaan & Yaxley, 2003). Many other aforementioned studies state similar property verification conclusions with distinct semantic categories. They confirm that to process these categories, the perceptual systems used at the time of their encoding are re-enacted (Niedenthal et al., 2005). However, whether these words can serve as cues to capture and direct spatial attention - and in which manner - is a different question entirely.

Visual symbols aid people to navigate their social environment and are "*nothing more than a social convention by means of which persons who know the convention direct one another's attention to particular aspects of their shared world*" (Tomasello & Call, 1997, p. 408). In this sense, commonly used locatives (e.g., 'left'/'right') have been suggested to shift spatial attention both overtly (accompanied with eye-movements) and covertly (without eye-movements) (Hunt & Kingstone, 2003). Likewise, word pointers can produce interference in stroop-like paradigms (Baldo et al., 1998). This suggests that the semantic processing of the words meddles with spatial responses. Hommel and colleagues (2001) investigated if centrally-presented word cues (left, right, above, below) affected detection, inhibition of return, and color discrimination tasks. The words (as well as the arrows) were task-irrelevant, that is, they were no more likely to coincide with the targets' location than with the non-target location. Participants could not build any target expectancies based on the cues. Across the three tasks (although the effect of words was more pronounced in the detection task) they observed that these nonpredictive symbolic cues led to automatic attention orienting that facilitated peripheral performance in the cue-consistent direction. Importantly, the authors argue that reflexive attention can be attained by means of centrally presented words when these are sufficiently overlearned and entrenched in common discourse. When they reach this point of familiarity, words can be equated to other less ambiguous communicative signals that are processed without great complexity, like arrows. Thus, so-called endogenous cues (i.e. which require interpretation) that do not share the possible target location (like exogenous, peripheral cues, i.e., a sudden flashlight onset) are effective means of automatic attention orienting. Importantly, involuntary allocation of attention attends to contextual priority. That is, when we are faced with more than one symbol (e.g., word) at the time, and since we cannot shift attention to more than one direction simultaneously, the symbol that is relevant for the current goal (task-relevant) will capture attention (e.g., contingent automaticity, Pratt & Hommel, 2003). This scenario often occurs in real-life settings where people are exposed to complex layers of semantic directional information that nevertheless are capable of guiding visual attention (see Wu et al., 2014 for a review). Other laboratory studies have confirmed that these conventional word terms reliably control the distribution of attention to cued locations in a more or less automatic fashion (B. S. Gibson et al., 2009; B. S. Gibson & Kingstone, 2006; Mayer & Kosson, 2004).

Gibson and Kingstone (2006) have taken a deep dive into the distinction between central and peripheral cues and the attention control which of them exerts. Broadly, they propose a new taxonomy based on the spatial relations that cues communicate which would elicit distinct types of attention control (reflexive or voluntary) more so than cue location itself. Projective cues would be words that express projective relations taking the self as referent (above, below, left, right) and deictic cues (arrow, eye-gaze, abrupt onsets) express more context-dependent spatial relations. As such, projective cues impose the activation of a reference frame and are therefore more complex to interpret. In contrast, deictic cues are effortlessly processed and paired with likely target locations. This distinction translates into different behavioral outputs: performance is decreased for projective relative to deictic cues. In addition, not all words are equal: ‘above’ and ‘below’ are accessed more efficiently than ‘left’ and ‘right’, presumably because the first are more primary, gravitationally experienced categories (Logan, 1995). A complementary explanation is that, from a statistical learning perspective, ‘above’ and ‘below’ always denote the same spatial referents while encounters with categories of ‘left’ and ‘right’ are often more ambiguous, inconsistent, and context-dependent (B. S. Gibson et al., 2009). The bottom line is this: differences in the processing of these words confirm that a reference frame is called upon to process them or else performance would be equal for all words tested. The authors then suggest that the capacity for a spatial cue to trigger automatic attention shifts is dependent on the complexity of the cue, as well as on the processing effort the cue imposes on the cognizer. Thus, word cues, with distinct degrees of semantic intricacies, are evidently more complex to process than other symbolic, yet deictic, cues.

Nevertheless, several studies employing words pertaining to categories abstract in nature (e.g., time-, number-, politics-, agency-, and affect-related Bertels et al., 2010; Bettinsoli et al., 2019; Farias et al., 2013; Ouellet, Santiago, Funes, et al., 2010; Weger & Pratt, 2008) have suggested that rather complex terms can too spatially orient visual attention. However, the core focus to most of these studies was to ascertain, with distinct tasks and methodologies, that vertical and horizontal coordinates anchor abstract categories, which in turn induce spatial congruity in their corresponding locations and enhance performance. Few have monitored eye movements (e.g., Bettinsoli et al., 2019) making it therefore very difficult to draw any conclusions as to whether these words can effectively grab and orient attention and in which manner.

Not only visual stimuli but other, albeit less explored, sensory modalities have been shown to cue visual attention to spatial locations. It is worth mentioning that some cross-modal evidence exists for the attention-capturing properties of tactile and olfactive inputs, more neglected but effective mediums of attention orienting (Spence et al., 2001; Spence & McGlone, 2001). As for audition, it is established that visual attention is attracted to the location of an auditory stimuli (Mazza et al., 2007; Schmitt et al., 2000; Spence & Driver, 1994). In fact, a single auditory tone carrying no spatial information but presented concomitantly with a visually cluttered environment guides attention to a visual event rendering it more salient and improving its detection (Dalton & Spence, 2007; Van der Burg et al., 2008). Moreover, visual attention is reflexively drawn to auditory-conveyed locations. Kean and Crawford (2008) manipulated the expectancies of the auditory cue informing visual target location (80%, 50%, and 20% probability) and observed significant better behavioral and eye-movement performance for the cued side of the screen even when target location was against probabilities. This processing advantage indicates that auditory information is unavoidable even when people are aware that the target is more likely to appear elsewhere. The structural link between vision and audition in attention orienting is likely biological and adaptive (Spence & Driver, 1997), as humans benefit from integrated and sensory-rich inspections of their vicinities. It is thus not surprising that auditory cues presented as being in the near surroundings of participants give rise to reduced eye-movement latencies although targets are placed in distant peripheral locations (Kean & Crawford, 2008). Basically, people can accurately discern the spatial distance of a presented auditory event, adjusting their eye-movements accordingly.

It seems that performance gains can even be achieved by presenting redundant multimodal information. Simultaneously presenting up to four sources of auditory and visual combinations of congruent information produces roughly 30% faster responses than single, double, and triple sources (Selcon et al., 1995). This evidence is in line with research showing that temporally colocalized multimodal cues (e.g., cue information in two different modalities presented simultaneously) intensify attention allocation and support each other to produce supper-addictive cueing effects above those evoked by single unimodal primes (Wallace et al., 1998). For example, Ngo & Spence (2010), in an attempt to replicate Van der Burg's and colleagues (2008, 2009) auditory–visual pip-and-pop and tactile–visual paradigms, demonstrated that exposing participants to synchronized nonvisual cues (auditory or vibrotactile) substantially facilitated visual search performance to a color-changing target.

Nevertheless, inconclusive evidence has questioned the capacity for bimodal cues to capture attention more efficiently than their unimodal constituents (Santangelo et al., 2006; Ward et al., 1998).

Similar cross-modal cueing experiments (i.e., where cue and target pertain to different modalities) typically report a facilitation in performance when the cue and target sensory modalities coincide in their directional content (Dufour, 1999; Spence & Driver, 1994, 1997). However, while Kean and Crawford's results (as well as similar others, Ward, 1994) can owe to a simple spatial stimulus-response overlap, Spence and Driver's (1997) cannot, as auditory cues provided absolutely no information concerning the target location hence generating a true attentional effect (although the reserve has not observed: visual cues did not influence auditory targets). Ward and colleagues (2000) obtained the exact opposite asymmetries in a procedure immune to response-priming effects: visual cues oriented spatial attention to auditory targets but not the other way around. They contend that the complexity of the stimulus condition (one or more cue/target modalities, number of cues, etc.), and not necessarily the modality of the stimulus per se, can facilitate or impede cueing effects. Specifically, when two modalities are at play, a complex cue environment and a simple target environment would favor visual cues over auditory targets (Ward, 1994), whilst a simple cue environment and a more complex target environment would favor auditory cues over visual targets (Spence & Driver, 1997). Presumably, auditory primes in complex cue settings fail to affect visual targets because individuals are simply not able to deduct spatial location under such cognitive overload. When both cue and target environments are simple, auditory cues orient both auditory and visual attention (Ward et al., 2000). Indeed, many perceptual phenomena are dominated by the visual modality over other sensory inputs (see Spence et al., 2011 for a review). Ho and Spence (2006) also report facilitated target discrimination on cued location following visual but not auditory directional cues (words 'left'/ 'right'). They also support their findings in terms of higher perceptual demands imposed by the discrimination task on the auditory versus the visual cueing condition.

Research employing abstract words as cues has further shown that left-right orienting of attention is not restricted to the visual modality. In establishing the spatial mapping of time, Ouellet and colleagues (2010) revealed that time-related words presented auditorily cue attention (although eye-movement measures were not recorded) and decreased keypress latencies on visual targets. This evidence simultaneously: a) informs that cross-modal cueing is effective with abstract categories serving as attentional primes, and b) casts aside the possibility that the effects are due to the oculomotor mechanics involved in the activity of reading (which do not occur for audition). Likewise, auditory stimulus presented binaurally, i.e., creating a sense of being presented centrally and thus ‘unlocalizable’, are also able to guide spatial attention toward their implied direction (Farias et al., 2013; Lakens et al., 2011). Although assessing the attentional properties of abstract words was not the major goal of these studies, and despite having relied mostly on simple disambiguation or detection tasks that provide little information on attentional biases, these studies indicate that not only unimodal but cross-modal attention priming is possible with such categories.

Research questions and overview

In the previous parts, I have covered the theoretical background that sustains the goals of this research program. The general aim of the proposed project is to elucidate how writing habits may affect areas of mental functioning and consequently shape how our social environment is apprehended. The main research questions I sought to answer with this dissertation are the following: How do horizontal asymmetries derived from habitualized scanning habits affect cognition as a social and situated system? Specifically, do we draw on the lateralized routines of reading and writing to represent human agency in a biased manner as well as other horizontally anchored abstract categories? And if so, do these asymmetries constrain visuospatial attention, motor performance, and expectancies concerning social and non-social targets? These and other questions were investigated in the present set of studies.

To this end, a series of seven studies is outlined, drawing from prior solid research revolving around six main tenets:

a) Reading and writing activities ground the asymmetrical direction of human motion and exert a pervasive impact on diverse cognitive processes (e.g., Chatterjee et al., 1995; Dobel et al., 2007; Maass et al., 2007, 2009; Maass & Russo, 2003; Suitner & Maass, 2016);

b) Abstract categories of time and politics are communicated through linguistic metaphors that rely on physical spatial properties and are anchored in the left-right horizontal continuum (e.g., Casasanto & Boroditsky, 2008; Farias et al., 2016; Mills et al., 2015; Oppenheimer & Trail, 2010; Ouellet, Santiago, Funes, et al., 2010; Santiago et al., 2010a);

c) The phenomena on a) and b) are observable in both left-to-right and right-to-left speaking samples (e.g., Afsari et al., 2018; Bettinsoli et al., 2019; Sylvie Chokron & De Agostini, 2000; Hernandez et al., 2017; Ouellet, Santiago, Israeli, et al., 2010);

d) The human attention system is biased in a manner consistent with the trajectory of language script (e.g., Afsari et al., 2016b; Casasanto & Bottini, 2014; Pollatsek et al., 1981b; Rinaldi et al., 2014a; Spalek & Hammad, 2004, 2005; von Hecker et al., 2016);

e) Faces, eye-gaze, and words can act as attention-orienting primes and effectively steer automatic spatial attention (e.g., Driver et al., 1999a; Estes et al., 2008; Friesen & Kingstone, 1998b; B. S. Gibson & Kingstone, 2006; Hommel et al., 2001);

f) The priming effects on e) occur for words both in visual and auditory modalities and in cross-modal and multimodal priming settings (e.g., Ho & Spence, 2006; M K Ngo & Spence, 2010; Schmitt et al., 2000; Spence & Driver, 1994; Ward et al., 2000a);

An adaptation of a broadly replicated task – the spatial cueing paradigm (Posner, 1980) – was employed to test the influence of distinct types of stimuli on the deployment of spatial attention and manual performance. The task demonstrates how the proposed rightward bias derived from learned spatial routines guides attention, therefore shaping detection latencies of targets embedded in the left and right hemifields. The general assumption is that there is an advantage for target detection when its location spatially coincides with the convention of text direction conveyed by the cue. Participants were primed with different cues manipulated along the horizontal axis. That is, the directional content of the cue (semantic or otherwise) was in line with or against script direction (e.g., profile faces, politically- and time-related words). The SAB-derived expectation is that cues aligned with the left-to-right or right-to-left flow of reading habits would drive attention asymmetrically favoring the detection of and gaze movements to targets in the corresponding peripheral visual field.

The studies went one step further by comparing: a) two cues very distinct but suggested to trigger similar automatic attention shifts (faces and words), b) two abstract categories both grounded horizontally but semantically dissimilar and different in the presence they maintain in colloquial discourse (time and politics), and c) the presentation of cues in two modalities (visual and auditory), separate and combined. In addition, comparing different sensory modalities in unimodal (visual-visual), cross-modal (auditory-visual) and multimodal (visual + auditory – visual) cue-target settings elucidates whether spatial biases: a) converge across modalities or not, and b) are a product of the physical act of reading or are embodied representations. These combinations and the control of attention they exert were assessed in six of the seven reported studies and, depending on the studies, with manual and ocular measures. The studies were devised such that design and stimuli complexity were gradually increasing which permitted to isolate the relative impact of each contributing factor as well as their combined effect. The reutilization of a classical paradigm ensured robustness to the methodology underlying these studies while bringing to the fore novel but interrelated contributes to fundamental research with potential applied consequences to:

a) How the positioning of stimuli on the horizontal dimension shapes agency-related and other inferences made about social targets;

b) The underlying processes orienting attention following directional script-coherent cues, and influencing lateralized detection decisions;

c) The individual and joint contribution of multiple modalities (visual and auditory) in grounding abstract social categories.

The next parts furnish details on the seven studies conducted to attain the aims of this dissertation. This empirical section is composed of five chapters which correspond to empirical articles containing original research:

II. *Social inferences from faces as a function of the left-to-right movement continuum.* This chapter examined whether the attribution of trait dimensions to social actors (with front or averted faces), agency-related (e.g., dominance, power, activity) and others conventionally assessed in research on impression formation from faces (e.g., warmth, familiarity, trustworthiness), is shaped by the spatial bias acquired from scanning habits. Trait judgments were successfully captured by two dimensions: power (agentic traits) and social-warmth (communal traits). The leftward and rightward averted profiles gave rise to different trait assignments such that rightward faces, in line with text direction, promoted a greater endorsement of agentic traits over communal ones. Gender effects are also reported. The chapter demonstrates that biased agency perceptions derived from spatially-specific routines generalize to other socially relevant inferences.

III: *Looking 'right': Asymmetric practices of reading and writing shape visuospatial attention and detection.* This chapter reports two studies. It focuses on investigating if directional face cues - profile faces with corresponding averted gaze - can trigger attention asymmetrically and constrain detection decisions to targets in peripheral left and right visual fields. The first study recorded behavioral measures alone and assessed the effects on three response intervals. The second study adds a process measure by recording participants' eye-movements. A disparity between congruent conditions was observed whereby right-oriented faces facilitated gaze movements and response times to targets on the right hemifield above the left face-left target pairs. The two studies show that the distribution of visuospatial attention is not arbitrary but unfolds consistently with the direction of reading and writing practices.

IV. *Two cultural processing asymmetries drive spatial attention.* This chapter consists of two studies. The underlying premise resembles the one explored in the previous chapter but extends its conclusions. In these studies, face cues were replaced by abstract word cues known to evoke left and right spatial representations. Both studies employed temporal words pertaining to the past and future (e.g., yesterday, before, tomorrow, after) delivered in the visual and auditory modality. We tested how two sources of bias, the semantic indication of the cues and the habitualized script direction, contribute to an asymmetric visuomotor performance. Critically, these complementary attention-orienting forces were tested in communities with opposite orthographic directions: Portuguese (left-to-right, experiment 1) and Arabic (right-to-left, experiment 2). Gaze movement (exp. 1) and speed of discrimination decisions (exp.1-2) of targets presented to the left or right hemifields were assessed. Aside from the predicted congruency effect, the special combination of future words that embodies the time concept and the language direction gave rise to a mirrored asymmetric performance between samples. There was a right-sided advantage for Portuguese participants and left-sided advantage for Arabic participants. This asymmetry in detection decisions was not differentiated between auditory and visual presentation. Attention measures further revealed that eye movement landed earlier on the target set that coincided with the trajectory imposed by reading routines (exp. 1). The two studies show that spatial instances of time act as attention facilitators that are shaped by the habitual movement direction.

V. *Reading and writing direction biases visuospatial attention: The case for politics.* This single study extended the findings with the time words to the less examined category of politics. Political words pertaining to the left and right of the political spectrum (e.g., demonstration, strike, profit, consumerism) were used as cues in the same spatial cueing task. Motor and gaze movements as a function of the anchor of political terms and cultural reading direction were recorded in a Portuguese speaking sample. We observed the predicted rightward asymmetry. Conservatism-related words that encompass the habitual left-to-right eye-trajectory trajectory of participants gave rise to faster attention and detection on the right space than did socialism-related words on the left space. Again, the spatial mapping of political instances was convergent across visual and auditory presentation of cue words. We conclude that the category of politics, despite being having less physical spatial associations, is likewise susceptible to be biased by conventional scanning routines.

VI. *The effect of simultaneously presented words and auditory tones on visuomotor performance.* This chapter reports a single study. The study integrates three premises: 1) reading and writing activities drive attention asymmetrically; b) time-related words orient spatial attention; and c) a nonspatial auditory tone improves visual spatial search. Visual time words were simultaneously presented concurrently with a noninformative auditory tone prior to target onset. The bimodal cues were compared with conditions of single auditory tone, single visual word, and no prime presentation. Contrary to what was hypothesized, bimodal cues (visual word + auditory tone), relative to unimodal visual cues, did not speed up attention and detection by rendering the targets more salient but impaired their detection instead. Results are discussed in terms of the advantages and disadvantages of simultaneously integrating two competing modalities in spatial attention.

The final chapter brings together the seven experiments and provides a general discussion of their main findings. Lastly, the limitations of this dissertation as well as avenues for future research, and practical implications are addressed.

References

Abele, A. E. (2003). The dynamics of masculine-agentic and feminine-communal traits: Findings from a prospective study. *Journal of Personality and Social Psychology*, *85*(4), 768–776. https://doi.org/10.1037/0022-3514.85.4.768

Abele, A. E., Uchronski, M., Suitner, C., & Wojciszke, B. (2008). Towards an operationalization of the fundamental dimensions of agency and communion: Trait content ratings in five countries considering valence and frequency of word occurrence. *European Journal of Social Psychology*, *38*(7), 1202–1217. https://doi.org/10.1002/ejsp.575

Abrams, R. A., Meyer, D. E., & Kornblum, S. (1990). Eye-hand coordination: Oculomotor control in rapid aimed limb movements. In *Journal of Experimental Psychology: Human Perception and Performance* (Vol. 16, Issue 2, pp. 248–267). American Psychological Association. https://doi.org/10.1037/0096-1523.16.2.248

Adams, F. M., & Osgood, C. E. (1973). A cross-cultural study of the affective meanings of color. *Journal of Cross-Cultural Psychology*, *4*(2), 135–156. https://doi.org/10.1177/002202217300400201

Afsari, Z., Keshava, A., Ossandón, J. P., & König, P. (2018). Interindividual differences among native right-to-left readers and native left-to-right readers during free viewing task. *Visual Cognition*, *26*(6), 430–441. https://doi.org/10.1080/13506285.2018.1473542

Afsari, Z., Ossandón, J. P., & König, P. (2016). The dynamic effect of reading direction habit on spatial asymmetry of image perception. *Journal of Vision*, *16*(11), 8–8. https://doi.org/10.1167/16.11.8

Arian, A., & Shamir, M. (1983). The primarily political functions of the left-right continuum. *Comparative Politics*, *15*(2), 139–158. https://doi.org/10.2307/421673

Asch, S. E. (1958). The metaphor: A psychological inquiry. In R. Tagiuri & L. Petrullo (Eds.), *Person Perception and Interpersonal Behavior* (pp. 86–94).

Baldo, J. V, Shimamura, A. P., & Prinzmetal, W. (1998). Mapping symbols to response modalities: Interference effects on Stroop-like tasks. *Perception & Psychophysics*, *60*(3), 427–437. https://doi.org/10.3758/BF03206864

Bandura, A. (1989). Human agency in social cognitive theory. In *American Psychologist* (Vol. 44, Issue 9, pp. 1175–1184). American Psychological Association. https://doi.org/10.1037/0003-066X.44.9.1175

Bandura, A. (1995). *Self-efficacy in Changing Societies*. Cambridge University Press.

Bandura, A. (2006). Toward a psychology of human agency. *Perspectives on Psychological Science*, *1*(2), 164–180. https://doi.org/10.1111/j.1745-6916.2006.00011.x

Banerjee, P., Chatterjee, P., & Sinha, J. (2012). Is It light or dark? Recalling moral behavior changes perception of brightness. *Psychological Science*, *23*(4), 407–409. https://doi.org/10.1177/0956797611432497

Baron-Cohen, S. (1995). The eye direction detector (EDD) and the shared attention mechanism (SAM): Two cases for evolutionary psychology. In *Joint Attention: Its Origins and Role in Development* (pp. 41–59). Lawrence Erlbaum Associates, Inc.

Barsalou, L. W. (1999). Language comprehension: Archival memory or preparation for situated action? In *Discourse Processes* (Vol. 28, Issue 1, pp. 61–80). Routledge. https://doi.org/10.1080/01638539909545069

Barsalou, L. W. (2008). Grounded Cognition. *Annual Review of Psychology*, *59*(1), 617–645. https://doi.org/10.1146/annurev.psych.59.103006.093639

Barsalou, L. W., Niedenthal, P. M., Barbey, A. K., & Ruppert, J. A. (2003). Social embodiment. In *The psychology of learning and motivation: Advances in research and theory, Vol. 43.* (pp. 43–92). Elsevier Science.

Bayliss, A. P., & Tipper, S. P. (2006). Predictive gaze cues and personality judgments: Should eye trust you? *Psychological Science*, *17*(6), 514–520. https://doi.org/10.1111/j.1467-9280.2006.01737.x

Bergen, B. K., & Lau, T. T. C. (2012). Writing direction affects how people map space onto time. *Frontiers in Psychology*, *3*(APR), 109. https://doi.org/10.3389/fpsyg.2012.00109

Bergson, H. (2001). *A Evolução Criadora* (04–2001st ed.). Edições 70.

Bertels, J., Kolinsky, R., & Morais, J. (2010). Emotional valence of spoken words influences the spatial orienting of attention. *Acta Psychologica*, *134*(3), 264–278. https://doi.org/https://doi.org/10.1016/j.actpsy.2010.02.008

Bettinsoli, M. L., Maass, A., & Suitner, C. (2019). The first, the least and the last: Spatial asymmetries in memory and their relation to script trajectory. *Memory and Cognition*, *47*, 229–239. https://doi.org/10.3758/s13421-018-0861-1

Blair, I. V. (2002). The malleability of automatic stereotypes and prejudice. *Personality and Social Psychology Review*, *6*(3), 242–261. https://doi.org/10.1207/S15327957PSPR0603_8

Boroditsky, L. (2000). Metaphoric structuring: Understanding time through spatial metaphors. *Cognition*, *75*(1), 1–28. https://doi.org/10.1016/S0010-0277(99)00073-6

Boroditsky, L. (2001). Does language shape thought?: Mandarin and English speakers' conceptions of time. *Cognitive Psychology*, *43*(1), 1–22. https://doi.org/https://doi.org/10.1006/cogp.2001.0748

Boroditsky, L. (2011). How languages construct time. In *Space, Time and Number in the Brain* (pp. 333–341). Elsevier Inc. https://doi.org/10.1016/B978-0-12-385948-8.00020-7

Boroditsky, L., & Gaby, A. (2010). Remembrances of times east: Absolute spatial representations of time in an australian aboriginal community. *Psychological Science*, *21*(11), 1635–1639. https://doi.org/10.1177/0956797610386621

Borreggine, K. L., & Kaschak, M. P. (2006). The action–sentence compatibility effect: It's all in the timing. *Cognitive Science*, *30*(6), 1097–1112. https://doi.org/https://doi.org/10.1207/s15516709cog0000_91

Bosman, J. (1987). Persuasive effects of political metaphors. *Metaphor and Symbolic Activity*, *2*(2), 97–113. https://doi.org/10.1207/s15327868ms0202_2

Bowers, D., & Heilman, K. M. (1980). Pseudoneglect: Effects of hemispace on a tactile line bisection task. *Neuropsychologia*, *18*(4), 491–498. https://doi.org/https://doi.org/10.1016/0028-3932(80)90151-7

Bradshaw, J. L., Nettleton, N. C., Nathan, G., & Wilson, L. (1983). Head and body space to left and right, front and rear—II. Visuotactual and kinesthetic studies and left-side underestimation. *Neuropsychologia*, *21*(5), 475–486. https://doi.org/https://doi.org/10.1016/0028-3932(83)90004-0

Bradshaw, J. L., Nettleton, N. C., Nathan, G., & Wilson, L. (1985). Bisecting rods and lines: Effects of horizontal and vertical posture on left-side underestimation by normal subjects. *Neuropsychologia*, *23*(3), 421–425. https://doi.org/https://doi.org/10.1016/0028-3932(85)90029-6

Brandt, M. J., IJzerman, H., & Blanken, I. (2014). Does recalling moral behavior change the perception of brightness? A replication and meta-analysis of Banerjee, Chatterjee, and Sinha (2012). *Social Psychology*, *45*(3), 246–252. https://doi.org/10.1027/1864-9335/a000191

Bratman, M. E. (1999). *Faces of intention: Selected essays on intention and agency*. Cambridge University Press.

Briñol, P., & Petty, R. E. (2003). Overt head movements and persuasion: A self-validation analysis. In *Journal of Personality and Social Psychology* (Vol. 84, Issue 6, pp. 1123–1139). American Psychological Association. https://doi.org/10.1037/0022-3514.84.6.1123

Briñol, P., & Petty, R. E. (2008). Embodied persuasion: Fundamental processes by which bodily responses can impact attitudes. In *Embodied grounding: Social, cognitive, affective, and neuroscientific approaches.* (pp. 184–207). Cambridge University Press. https://doi.org/10.1017/CBO9780511805837.009

Briñol, P., Petty, R. E., & Wagner, B. (2009). Body posture effects on self-evaluation: A self-validation approach. *European Journal of Social Psychology*, *39*(6), 1053–1064. https://doi.org/https://doi.org/10.1002/ejsp.607

Brooks, J. L., Sala, S. Della, & Darling, S. (2014). Representational pseudoneglect: A review. *Neuropsychology Review*, *24*(4), 148–165. https://doi.org/10.1007/s11065-013-9245-2

Bulf, H., de Hevia, M. D., Gariboldi, V., & Cassia, V. M. (2017). Infants learn better from left to right: A directional bias in infants' sequence learning. *Scientific Reports*, *7*(2437). https://doi.org/10.1038/s41598-017-02466-w

Burns, T. R., & Dietz, T. (1992). Cultural evolution: Social rule systems, selection and human agency. *International Sociology*, *7*(3), 259–283. https://doi.org/10.1177/026858092007003001

Buss, D. M. (1994). The strategies of human mating. *American Scientist*, *82*(3), 238–249.

Byrne, R. W., & Whiten, A. (1991). Computation and mindreading in primate tactical deception. In *Natural Theories of Mind: Evolution, Development and Simulation of Everyday Mindreading* (pp. 127–141). Basil Blackwell.

Cacioppo, J. T., Priester, J. R., & Berntson, G. G. (1993). Rudimentary determinants of attitudes: II. Arm flexion and extension have differential effects on attitudes. In *Journal of Personality and Social Psychology* (Vol. 65, Issue 1, pp. 5–17). American Psychological Association. https://doi.org/10.1037/0022-3514.65.1.5

Carnaghi, A., Piccoli, V., Brambilla, M., & Bianchi, M. (2014). Gender hierarchy in the space: The role of gender status in shaping the spatial agency bias. *The Journal of Social Psychology*, *154*(2), 105–114. https://doi.org/10.1080/00224545.2013.863174

Carr, L., Iacoboni, M., Dubeaut, M. C., Mazziotta, J. C., & Lenzi, G. L. (2003). Neural mechanisms of empathy in humans: A relay from neural systems for imitation to limbic areas. *Proceedings of the National Academy of Sciences of the United States of America*, *100*(9), 5497–5502. https://doi.org/10.1073/pnas.0935845100

Casasanto, D. (2009). Embodiment of abstract concepts: Good and bad in right- and left-handers. *Journal of Experimental Psychology: General*, *138*(3), 351–367. https://doi.org/10.1037/a0015854

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition*, *106*(2), 579–593. https://doi.org/10.1016/j.cognition.2007.03.004

Casasanto, D., & Bottini, R. (2014). Mirror reading can reverse the flow of time. *Journal of Experimental Psychology: General*, *143*(2), 473–479. https://doi.org/10.1037/a0033297

Casasanto, D., & Dijkstra, K. (2010). Motor action and emotional memory. *Cognition*, *115*(1), 179–185. https://doi.org/https://doi.org/10.1016/j.cognition.2009.11.002

Casini, L., & Macar, F. (1997). Effects of attention manipulation on judgments of duration and of intensity in the visual modality. *Memory & Cognition*, *25*(6), 812–818. https://doi.org/10.3758/BF03211325

Chasteen, A. L., Burdzy, D. C., & Pratt, J. (2010). Thinking of God moves attention. *Neuropsychologia*, *48*(2), 627–630. https://doi.org/https://doi.org/10.1016/j.neuropsychologia.2009.09.029

Chatterjee, A. (2002). Portrait profiles and the notion of agency. *Empirical Studies of the Arts*, *20*(1), 33–41. https://doi.org/10.2190/3wlf-agtv-0aw7-r2cn

Chatterjee, A., Maher, L. M., & Heilman, K. M. (1995). Spatial characteristics of thematic role representation. *Neuropsychologia*, *33*(5), 643–648. https://doi.org/https://doi.org/10.1016/0028-3932(94)00134-B

Cheal, M., & Lyon, D. R. (1991). Central and peripheral precuing of forced-choice discrimination. *The Quarterly Journal of Experimental Psychology Section A*, *43*(4), 859–880. https://doi.org/10.1080/14640749108400960

Chen, M., & Bargh, J. A. (1999). Consequences of automatic evaluation: Immediate behavioral predispositions to approach or avoid the stimulus. *Personality and Social Psychology Bulletin*, *25*(2), 215–224. https://doi.org/10.1177/0146167299025002007

Chokron, S. (2002). On the origin of free-viewing perceptual asymmetries. In *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior* (Vol. 38, Issue 2, pp. 109–112). Masson Italia. https://doi.org/10.1016/S0010-9452(08)70644-0

Chokron, S., Bartolomeo, P., Perenin, M. T., Helft, G., & Imbert, M. (1998). Scanning direction and line bisection: A study of normal subjects and unilateral neglect patients with opposite reading habits. *Cognitive Brain Research*, *7*(2), 173–178. https://doi.org/10.1016/S0926-6410(98)00022-6

Chokron, S., & De Agostini, M. (2000). Reading habits influence aesthetic preference. *Cognitive Brain Research*, *10*(1–2), 45–49. https://doi.org/10.1016/S0926-6410(00)00021-5

Chokron, S., & Imbert, M. (1993). Influence of reading habits on line bisection. *Cognitive Brain Research*, *1*(4), 219–222. https://doi.org/10.1016/0926-6410(93)90005-P

Clark, H. H. (1973). Space, time, semantics, and the child. In T. Moore (Ed.), *Cognitive Development and the Acquisition of Language* (pp. xii, 308–xii, 308). Academic Press.

Cohen, D., & Leung, A. K.-Y. (2009). The hard embodiment of culture. *European Journal of Social Psychology*, *39*(7), 1278–1289. https://doi.org/https://doi.org/10.1002/ejsp.671

Coleman, J. S. (1986). Social theory, social research, and a theory of action. *American Journal of Sociology*, *91*(6), 1309–1335. https://doi.org/10.1086/228423

Conson, M., Cinque, F., Barbarulo, A. M., & Trojano, L. (2008). A common processing system for duration, order and spatial information: evidence from a time estimation task. *Experimental Brain Research*, *187*(2), 267–274. https://doi.org/10.1007/s00221-008-1300-5

Coslett, H. B. (1999). Spatial influences on motor and language function. *Neuropsychologia*, *37*(6), 695–706. https://doi.org/https://doi.org/10.1016/S0028-3932(98)00116-X

Crawford, L. E., Margolies, S. M., Drake, J. T., & Murphy, M. E. (2006). Affect biases memory of location: Evidence for the spatial representation of affect. *Cognition and Emotion*, *20*(8), 1153–1169. https://doi.org/10.1080/02699930500347794

Cuddy, A. J. C., Fiske, S. T., & Glick, P. B. T.-A. in E. S. P. (2008). *Warmth and competence as universal dimensions of social perception: The stereotype content model and the BIAS map* (Vol. 40, pp. 61–149). Academic Press. https://doi.org/https://doi.org/10.1016/S0065-2601(07)00002-0

Dalton, P., & Spence, C. (2007). Attentional capture in serial audiovisual search tasks. *Perception and Psychophysics*, *69*(3), 422–438. https://doi.org/10.3758/BF03193763

Damásio, A. (2011). *O Erro de Descartes – Emoção, razão e cérebro humano*. Temas e Debates.

De Dreu, C. K. W., Giacomantonio, M., Shalvi, S., & Sligte, D. (2009). Getting stuck or stepping back: Effects of obstacles and construal level in the negotiation of creative solutions. *Journal of Experimental Social Psychology*, *45*(3), 542–548. https://doi.org/https://doi.org/10.1016/j.jesp.2009.01.001

de Hevia, M. D., Girelli, L., Addabbo, M., & Macchi Cassia, V. (2014). Human infants' preference for left-to-right oriented increasing numerical sequences. *PLoS ONE*, *9*(5), e96412. https://doi.org/10.1371/journal.pone.0096412

de Hevia, M. D., & Spelke, E. S. (2009). Spontaneous mapping of number and space in adults and young children. *Cognition*, *110*(2), 198–207. https://doi.org/https://doi.org/10.1016/j.cognition.2008.11.003

De Jaegher, H., & Di Paolo, E. (2007). Participatory sense-making: An enactive approach to social cognition. *Phenomenology and the Cognitive Sciences*, *6*(4), 485–507. https://doi.org/10.1007/s11097-007-9076-9

De Jaegher, H., Di Paolo, E., & Gallagher, S. (2010). Can social interaction constitute social cognition? *Trends in Cognitive Sciences*, *14*(10), 441–447. https://doi.org/10.1016/j.tics.2010.06.009

de Kerckhove, D., & Lumsden, C. (1988). The alphabet and the brain: The lateralization of writing. In *The Alphabet and the Brain*. Springer-Verlag Berlin Heidelberg. https://doi.org/10.1007/978-3-662-01093-8

Dehaene, S., Bossini, S., & Giraux, P. (1993). The mental representation of parity and number magnitude. *Journal of Experimental Psychology: General*, *122*(3), 371–396. https://doi.org/10.1037/0096-3445.122.3.371

Dewey, J. (2008). The later works of John Dewey, 1925-1953: Experience and Nature. In J. A. Boydston (Ed.), *Southern Illinois University Press: Vol. I: 1925*. Southern Illinois University Press.

Diekamp, B., Regolin, L., Güntürkün, O., & Vallortigara, G. (2005). A left-sided visuospatial bias in birds. In *Current biology : CB* (Vol. 15, Issue 10, pp. R372-3). https://doi.org/10.1016/j.cub.2005.05.017

Dobel, C., Diesendruck, G., & Bölte, J. (2007). How writing system and age influence spatial representations of actions: A developmental, cross-linguistic study. *Psychological Science*, *18*(6), 487–491. https://doi.org/10.1111/j.1467-9280.2007.01926.x

Dobzhansky, T. (1972). Genetics and the diversity of behavior. In *American Psychologist* (Vol.

27, Issue 6, pp. 523–530). American Psychological Association. https://doi.org/10.1037/h0032957

Dooley, C. M. (2010). Young children’s approaches to books: The emergence of comprehension. *The Reading Teacher*, *64*(2), 120–130. https://doi.org/https://doi.org/10.1598/RT.64.2.4

Dove, G. (2016). Three symbol ungrounding problems: Abstract concepts and the future of embodied cognition. *Psychonomic Bulletin & Review*, *23*(4), 1109–1121. https://doi.org/10.3758/s13423-015-0825-4

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, *6*(5), 509–540. https://doi.org/10.1080/135062899394920

Dryer, M. S. (2011). Order of subject, object and verb. In M. S. Dryer & M. Haspelmath (Eds.), *The World Atlas of Language Structures Online*. http://wals.info/chapter/81%0D

Dufour, A. (1999). Importance of attentional mechanisms in audiovisual links. *Experimental Brain Research*, *126*(2), 215–222. https://doi.org/10.1007/s002210050731

Dunbar, N. E. (2004). Theory in progress: Dyadic power theory: Constructing a communication-based theory of relational power. *Journal of Family Communication*, *4*(3–4), 235–248. https://doi.org/10.1080/15267431.2004.9670133

Elmore, K. C., & Luna-Lucero, M. (2016). Light bulbs or seeds? How metaphors for ideas influence judgments about genius. *Social Psychological and Personality Science*, *8*(2), 200–208. https://doi.org/10.1177/1948550616667611

Estes, Z., Verges, M., & Barsalou, L. W. (2008). Head up, foot down: Object words orient attention to the objects’ typical location: Research report. *Psychological Science*, *19*(2), 93–97. https://doi.org/10.1111/j.1467-9280.2008.02051.x

Eviatar, Z. (1995). Reading direction and attention - Effects on lateralized ignoring. *Brain and Cognition*, *29*(2), 137–150. https://doi.org/https://doi.org/10.1006/brcg.1995.1273

Fagard, J., & Dahmen, R. (2003). The effects of reading-writing direction on the asymmetry of space perception and directional tendencies: A comparison between French and Tunisian children. *Laterality*, *8*(1), 39–52. https://doi.org/10.1080/713754473

Farias, A. R., Garrido, M. V., & Semin, G. R. (2013). Converging modalities ground abstract categories: The case of politics. *PLoS ONE*, *8*(4), e60971. https://doi.org/10.1371/journal.pone.0060971

Farias, A. R., Garrido, M. V., & Semin, G. R. (2016). Embodiment of abstract categories in space. . . grounding or mere compatibility effects? The case of politics. *Acta Psychologica*, *166*, 49–53. https://doi.org/10.1016/j.actpsy.2016.03.002

Faust, M., Kravetz, S., & Netzer, E. (2002). Effects of sentential context on the processing of unambiguous words by the two cerebral hemispheres. *Brain and Language*, *80*(3), 438–448. https://doi.org/https://doi.org/10.1006/brln.2001.2601

Fischer, M. H., Castel, A. D., Dodd, M. D., & Pratt, J. (2003). Perceiving numbers causes spatial shifts of attention. *Nature Neuroscience*, *6*(6), 555–556. https://doi.org/10.1038/nn1066

Fischer, M. H., & Zwaan, R. A. (2008). Embodied language: A review of the role of the motor system in language comprehension. *Quarterly Journal of Experimental Psychology*, *61*(6), 825–850. https://doi.org/10.1080/17470210701623605

Fiske, A. P. (2004). Four modes of constituting relationships: Consubstantial assimilation; Space, magnitude, time, and force; Concrete procedures; Abstract symbolism. In *Relational Models Theory: A Contemporary Overview* (pp. 61–146). Lawrence Erlbaum Associates Publishers.

Fiske, S. T. (1992). Thinking is for doing: Portraits of social cognition from Daguerreotype to laserphoto. In *Journal of Personality and Social Psychology* (Vol. 63, Issue 6, pp. 877–889). American Psychological Association. https://doi.org/10.1037/0022-3514.63.6.877

Fiske, S. T., Cuddy, A. J. C., & Glick, P. (2007). Universal dimensions of social cognition: Warmth and competence. *Trends in Cognitive Sciences*, *11*(2), 77–83. https://doi.org/https://doi.org/10.1016/j.tics.2006.11.005

Fitts, P. M., & Seeger, C. M. (1953). S-R compatibility: spatial characteristics of stimulus and response codes. *Journal of Experimental Psychology*, *46*(3), 199–210. https://doi.org/10.1037/h0062827

Flath, M. E., Smith, A. K., & Elias, L. J. (2019). Cultural differences in lateral biases on aesthetic judgments: The effect of native reading direction. *Culture and Brain*, *7*(1), 57–66. https://doi.org/10.1007/s40167-018-0062-6

Fodor, J. A. (1975). *The Language of Thought*. Harvard University Press.

Forceville, C. J., & Renckens, T. (2013). The good is light and bad is dark metaphor in feature films. *Metaphor and the Social World*, *3*(2), 160–179.

Foroni, F., & Semin, G. R. (2011). When does mimicry affect evaluative judgment? In *Emotion* (Vol. 11, Issue 3, pp. 687–690). American Psychological Association.

https://doi.org/10.1037/a0023163

Freyd, J. J., & Finke, R. A. (1984). Representational momentum. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *10*(1), 126–132. https://doi.org/10.1037/0278-7393.10.1.126

Friedrich, T. E., & Elias, L. J. (2016). The write bias: The influence of native writing direction on aesthetic preference biases. *Psychology of Aesthetics, Creativity, and the Arts*, *10*(2), 128–133. https://doi.org/10.1037/aca0000055

Friedrich, T. E., Harms, V. L., & Elias, L. J. (2014). Dynamic stimuli: Accentuating aesthetic preference biases. *Laterality*, *19*(5), 549–559. https://doi.org/10.1080/1357650X.2014.886585

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin and Review*, *5*(3), 490–495. https://doi.org/10.3758/BF03208827

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, *133*(4), 694–724. https://doi.org/10.1037/0033-2909.133.4.694

Galfano, G., Dalmaso, M., Marzoli, D., Pavan, G., Coricelli, C., & Castelli, L. (2012). Eye gaze cannot be ignored (but neither can arrows). *Quarterly Journal of Experimental Psychology*, *65*(10), 1895–1910. https://doi.org/10.1080/17470218.2012.663765

Gallagher, S. (2000). Philosophical conceptions of the self: implications for cognitive science. *Trends in Cognitive Sciences*, *4*(1), 14–21. https://doi.org/https://doi.org/10.1016/S1364-6613(99)01417-5

Gallese, V., Fadiga, L., Fogassi, L., & Rizzolatti, G. (1996). Action recognition in the premotor cortex. *Brain*, *119*(2), 593–609. https://doi.org/10.1093/brain/119.2.593

Gentner, D., Imai, M., & Boroditsky, L. (2002). As time goes by: Evidence for two systems in processing space → time metaphors. *Language and Cognitive Processes*, *17*(5), 537–565. https://doi.org/10.1080/01690960143000317

Gevers, W., Reynvoet, B., & Fias, W. (2003). The mental representation of ordinal sequences is spatially organized. *Cognition*, *87*(3), B87–B95. https://doi.org/10.1016/S0010-0277(02)00234-2

Gibbs, R. W. (1992). Categorization and metaphor understanding. In *Psychological Review* (Vol. 99, Issue 3, pp. 572–577). American Psychological Association.

https://doi.org/10.1037/0033-295X.99.3.572

Gibson, B. S., & Bryant, T. A. (2005). Variation in cue duration reveals top-down modulation of involuntary orienting to uninformative symbolic cues. *Perception and Psychophysics*, *67*(5), 749–758. https://doi.org/10.3758/BF03193530

Gibson, B. S., & Kingstone, A. (2006). Visual attention and the semantics of space: beyond central and peripheral cues. *Psychological Science*, *17*(7), 622–627. https://doi.org/10.1111/j.1467-9280.2006.01754.x

Gibson, B. S., Scheutz, M., & Davis, G. J. (2009). Symbolic control of visual attention: Semantic constraints on the spatial distribution of attention. *Attention, Perception, & Psychophysics*, *71*(2), 363–374. https://doi.org/10.3758/APP.71.2.363

Gibson, J. J. (1979). *The ecological approach to perception*. Houghton Mifflin.

Giessner, S. R., & Schubert, T. W. (2007). High in the hierarchy: How vertical location and judgments of leaders' power are interrelated. *Organizational Behavior and Human Decision Processes*, *104*(1), 30–44. https://doi.org/https://doi.org/10.1016/j.obhdp.2006.10.001

Girelli, L., Lucangeli, D., & Butterworth, B. (2000). The development of automaticity in accessing number magnitude. *Journal of Experimental Child Psychology*, *76*(2), 104–122. https://doi.org/https://doi.org/10.1006/jecp.2000.2564

Glaser, M., & Knops, A. (2020). When adding is right: Temporal order judgements reveal spatial attention shifts during two-digit mental arithmetic. *Quarterly Journal of Experimental Psychology*, *73*(7), 1115–1132. https://doi.org/10.1177/1747021820902917

Glenberg, A. M. (2008). Embodiment for education. In P. Calvo & A. Gomila (Eds.), *Handbook of cognitive science: An embodied approach* (pp. 355–372). Elsevier Science.

Glucksberg, S., & Keysar, B. (1990). Understanding metaphorical comparisons: Beyond similarity. *Psychological Review*, *97*(1), 3–18. https://doi.org/10.1037/0033-295X.97.1.3

Glucksberg, S., McGlone, M. S., & Manfredi, D. (1997). Property attribution in metaphor comprehension. *Journal of Memory and Language*, *36*(1), 50–67. https://doi.org/https://doi.org/10.1006/jmla.1996.2479

Göbel, S. M., McCrink, K., Fischer, M. H., & Shaki, S. (2018). Observation of directional storybook reading influences young children's counting direction. *Journal of Experimental Child Psychology*, *166*, 49–66. https://doi.org/https://doi.org/10.1016/j.jecp.2017.08.001

Goodsell, C. T. (1988). The architecture of parliaments: Legislative houses and political culture. *British Journal of Political Science*, *18*(3), 287–302. http://www.jstor.org/stable/193839

Grafton, S. T., Arbib, M. A., Fadiga, L., & Rizzolatti, G. (1996). Localization of grasp representations in humans by positron emission tomography. *Experimental Brain Research*, *112*(1), 103–111. https://doi.org/10.1007/BF00227183

Greenwald, A. G. (1970). Sensory feedback mechanisms in performance control: With special reference to the ideo-motor mechanism. In *Psychological Review* (Vol. 77, Issue 2, pp. 73–99). American Psychological Association. https://doi.org/10.1037/h0028689

Gregory, S. E. A., & Jackson, M. C. (2017). Joint attention enhances visual working memory. In *Journal of Experimental Psychology: Learning, Memory, and Cognition* (Vol. 43, Issue 2, pp. 237–249). American Psychological Association. https://doi.org/10.1037/xlm0000294

Griffin, Z. M. (2004). Why look? Reasons for eye movements related to language production. In *The Interface of Language, Vision, and Action: Eye movements and the Visual World* (pp. 213–247). Psychology Press.

Grosbras, M.-H., Laird, A. R., & Paus, T. (2005). Cortical regions involved in eye movements, shifts of attention, and gaze perception. *Human Brain Mapping*, *25*(1), 140–154. https://doi.org/https://doi.org/10.1002/hbm.20145

Haggard, P., & Tsakiris, M. (2009). The experience of agency: Feelings, judgments, and responsibility. *Current Directions in Psychological Science*, *18*(4), 242–246. https://doi.org/10.1111/j.1467-8721.2009.01644.x

Haidt, J., & Algoe, S. (2004). Moral amplification and the emotions that attach us to saints and demons. In *Handbook of Experimental Existential Psychology.* (pp. 322–335). Guilford Press.

Halpern, A. R., & Kelly, M. H. (1993). Memory biases in left versus right implied motion. In *Journal of Experimental Psychology: Learning, Memory, and Cognition* (Vol. 19, Issue 2, pp. 471–484). American Psychological Association. https://doi.org/10.1037/0278-7393.19.2.471

Hamilton, D. L., & Trolier, T. K. (1986). Stereotypes and stereotyping: An overview of the cognitive approach. In *Prejudice, discrimination, and racism.* (pp. 127–163). Academic Press.

Havelock, E. A., & Havelock, L. (1967). *Preface to Plato* (H. U. Press (ed.)).

Heath, R. L., Mahmasanni, O., Rouhana, A., & Nassif, N. (2005). Comparison of aesthetic preferences among Roman and Arabic script readers. *Laterality*, *10*(5), 399–411. https://doi.org/10.1080/13576500442000166

Hegarty, P., Lemieux, A. F., & McQueen, G. (2010). Graphing the order of the sexes: Constructing, recalling, interpreting, and putting the self in gender difference graphs. In *Journal of Personality and Social Psychology* (Vol. 98, Issue 3, pp. 375–391). American Psychological Association. https://doi.org/10.1037/a0018590

Hegarty, P., Watson, N., Fletcher, L., & McQueen, G. (2011). When gentlemen are first and ladies are last: Effects of gender stereotypes on the order of romantic partners' names. *British Journal of Social Psychology*, *50*(1), 21–35. https://doi.org/https://doi.org/10.1348/014466610X486347

Hernandez, M. D., Wang, Y., Sheng, H., Kalliny, M., & Minor, M. (2017). Escaping the corner of death? An eye-tracking study of reading direction influence on attention and memory. *Journal of Consumer Marketing*, *34*(1), 1–10. https://doi.org/10.1108/JCM-02-2016-1710

Hertz, R. (2013). The pre-eminence of the right hand: A study in religious polarity. *HAU: Journal of Ethnographic Theory*, *3*(2), 335–357. https://doi.org/10.14318/hau3.2.024

Hespos, S. J., & Spelke, E. S. (2004). Conceptual precursors to language. *Nature*, *430*(6998), 453–456. https://doi.org/10.1038/nature02634

Hietanen, J. K. (2002). Social attention orienting integrates visual information from head and body orientation. *Psychological Research*, *66*(3), 174–179. https://doi.org/10.1007/s00426-002-0091-8

Higgins, E. T. (1997). Beyond pleasure and pain. In *American Psychologist* (Vol. 52, Issue 12, pp. 1280–1300). American Psychological Association. https://doi.org/10.1037/0003-066X.52.12.1280

Higgins, E. T., & Bargh, J. A. (1987). Social cognition and social perception. *Annual Review of Psychology*, *38*(1), 369–425. https://doi.org/10.1146/annurev.ps.38.020187.002101

Hitlin, S., & Elder, G. H. (2007). Time, self, and the curiously abstract concept of agency. *Sociological Theory*, *25*(2), 170–191. https://doi.org/10.1111/j.1467-9558.2007.00303.x

Ho, C., & Spence, C. (2006). Verbal interface design: Do verbal directional cues automatically orient visual spatial attention? *Computers in Human Behavior*, *22*(4), 733–748. https://doi.org/10.1016/j.chb.2005.12.008

Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience*, *3*(1), 80–84. https://doi.org/10.1038/71152

Hoffmann, D., Hornung, C., Martin, R., & Schiltz, C. (2013). Developing number–space associations: SNARC effects using a color discrimination task in 5-year-olds. *Journal of Experimental Child Psychology*, *116*(4), 775–791. https://doi.org/https://doi.org/10.1016/j.jecp.2013.07.013

Hommel, B. (1996). The cognitive representation of action: Automatic integration of perceived action effects. *Psychological Research*, *59*(3), 176–186. https://doi.org/10.1007/BF00425832

Hommel, B., Pratt, J., Colzato, L., & Godijn, R. (2001). Symbolic control of visual attention. *Psychological Science*, *12*(5), 360–365. https://doi.org/10.1111/1467-9280.00367

Hood, B. M., Willen, J. D., & Driver, J. (1998). Adult's eyes trigger shifts of visual attention in human infants. *Psychological Science*, *9*(2), 131–134. https://doi.org/10.1111/1467-9280.00024

Hubbard, T. L. (1990). Cognitive representation of linear motion: Possible direction and gravity effects in judged displacement. *Memory & Cognition*, *18*(3), 299–309. https://doi.org/10.3758/BF03213883

Hubbard, T. L. (2005). Representational momentum and related displacements in spatial memory: A review of the findings. *Psychonomic Bulletin & Review*, *12*(5), 822–851. https://doi.org/10.3758/BF03196775

Hunt, A. R., & Kingstone, A. (2003). Covert and overt voluntary attention: linked or independent? *Cognitive Brain Research*, *18*(1), 102–105. https://doi.org/https://doi.org/10.1016/j.cogbrainres.2003.08.006

Iacoboni, M. (2009). Imitation, Empathy, and Mirror Neurons. *Annual Review of Psychology*, *60*(1), 653–670. https://doi.org/10.1146/annurev.psych.60.110707.163604

Ijzerman, H., & Semin, G. R. (2009). The thermometer of social relations: Mapping social proximity on temperature: Research article. *Psychological Science*, *20*(10), 1214–1220. https://doi.org/10.1111/j.1467-9280.2009.02434.x

IJzerman, H., & Semin, G. R. (2010). Temperature perceptions as a ground for social proximity. *Journal of Experimental Social Psychology*, *46*(6), 867–873. https://doi.org/https://doi.org/10.1016/j.jesp.2010.07.015

Ishihara, M., Keller, P. E., Rossetti, Y., & Prinz, W. (2008). Horizontal spatial representations of time: Evidence for the STEARC effect. *Cortex*, *44*(4), 454–461. https://doi.org/https://doi.org/10.1016/j.cortex.2007.08.010

Itier, R. J., Villate, C., & Ryan, J. D. (2007). Eyes always attract attention but gaze orienting is task-dependent: Evidence from eye movement monitoring. *Neuropsychologia*, *45*(5), 1019–1028. https://doi.org/https://doi.org/10.1016/j.neuropsychologia.2006.09.004

Ito, Y., & Hatta, T. (2004). Spatial structure of quantitative representation of numbers: Evidence from the SNARC effect. *Memory & Cognition*, *32*(4), 662–673. https://doi.org/10.3758/BF03195857

James, W. (1890). *The Principles of Psychology*. Henry Holt and Company.

Jewell, G., & McCourt, M. E. (2000). Pseudoneglect: A review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia*, *38*(1), 93–110. https://doi.org/10.1016/S0028-3932(99)00045-7

Joas, H. (1996). *The Creativity of Action*. University of Chicago Press.

Johnson, J. T., & Taylor, S. E. (1981). The effect of metaphor on political attitudes. *Basic and Applied Social Psychology*, *2*(4), 305–316. https://doi.org/10.1207/s15324834basp0204_6

Jonides, J. (1981). Voluntary versus automatic control over the mind’s eye. In J. Long & A. Baddeley (Eds.), *Attention and Performance IX* (pp. 187–203). Lawrence Erlbaum Associates.

Kahneman, D., & Tversky, A. (1973). On the psychology of prediction. *Psychological Review*, *80*(4), 237–251. https://doi.org/10.1037/h0034747

Kaschak, M. P., Zwaan, R. A., Aveyard, M., & Yaxley, R. H. (2006). Perception of auditory motion affects language processing. In *Cognitive Science* (Vol. 30, Issue 4, pp. 733–744). Lawrence Erlbaum. https://doi.org/10.1207/s15516709cog0000_54

Katz, A., & Law, A. (2010). Experimental support for conceptual metaphors with an episodic memory task. *Metaphor and Symbol*, *25*(4), 263–270. https://doi.org/10.1080/10926488.2010.510930

Kazandjian, S., Cavézian, C., Zivotofsky, A. Z., & Chokron, S. (2010). Bisections in two languages: When number processing, spatial representation, and habitual reading direction interact. *Neuropsychologia*, *48*(14), 4031–4037. https://doi.org/https://doi.org/10.1016/j.neuropsychologia.2010.10.020

Kazandjian, S., & Chokron, S. (2008). Paying attention to reading direction. *Nature Reviews*

Neuroscience, *9*(12), 965. https://doi.org/10.1038/nrn2456-c1

Kean, M., & Crawford, T. J. (2008). Cueing visual attention to spatial locations with auditory cues. *Journal of Eye Movement Research*, *2*(3), 1–13. https://doi.org/10.16910/jemr.2.3.4

Kebbe, H., & Vinter, A. (2012). How culture, age, and manual dominance affect directionality in drawing side view objects. *Journal of Cross-Cultural Psychology*, *44*(1), 160–172. https://doi.org/10.1177/0022022111435098

Kermani, M., Verghese, A., & Vidyasagar, T. R. (2018). Attentional asymmetry between visual hemifields is related to habitual direction of reading and its implications for debate on cause and effects of dyslexia. *Dyslexia*, *24*(1), 33–43. https://doi.org/10.1002/dys.1574

King, N., Ollendick, T. H., & Tonge, B. J. (1997). Children's nighttime fears. *Clinical Psychology Review*, *17*(4), 431–443. https://doi.org/https://doi.org/10.1016/S0272-7358(97)00014-7

Kintsch, W. (1998). The representation of knowledge in minds and machines. *International Journal of Psychology*, *33*(6), 411–420. https://doi.org/10.1080/002075998400169

Klein, R., Kingstone, A., & Pontefract, A. (1992). Orienting of visual attention. In *Eye Movements and Visual Cognition. Springer Series in Neuropsychology* (pp. 46–65). Springer.

Kövecses, Z. (2005). *Metaphor in Culture: Universality and Variation*. Cambridge University Press.

Lakens, D., Semin, G. R., & Foroni, F. (2012). But for the bad, there would not be good: Grounding valence in brightness through shared relational structures. In *Journal of Experimental Psychology: General* (Vol. 141, Issue 3, pp. 584–594). American Psychological Association. https://doi.org/10.1037/a0026468

Lakens, D., Semin, G. R., & Garrido, M. V. (2011). The sound of time: Cross-modal convergence in the spatial structuring of time. *Consciousness and Cognition*, *20*(2), 437–443. https://doi.org/10.1016/j.concog.2010.09.020

Lakoff, G. (1993). The contemporary theory of metaphor. In *Metaphor and thought, 2nd ed.* (pp. 202–251). Cambridge University Press. https://doi.org/10.1017/CBO9781139173865.013

Lakoff, G. (2012). Explaining embodied cognition results. *Topics in Cognitive Science*, *4*(4), 773–785. https://doi.org/https://doi.org/10.1111/j.1756-8765.2012.01222.x

Lakoff, G., & Johnson, M. (1980). The metaphorical structure of the human conceptual system. *Cognitive Science*, *4*, 195–208. https://doi.org/10.1016/S0364-0213(80)80017-6

Lakoff, G., & Johnson, M. (1999). *Philosophy in the flesh : the embodied mind and its challenge to Western thought*. Basic Books.

Lamer, S. A., Suitner, C., Maass, A., Caccioppoli, R., & Pradell, H. (2020). The function of vertical and horizontal space to social group identity. *Self and Identity*, 1–37. https://doi.org/10.1080/15298868.2020.1785929

Lamer, S. A., & Weisbuch, M. (2019). Men over women: The social transmission of gender stereotypes through spatial elevation. *Journal of Experimental Social Psychology*, *84*, 103828. https://doi.org/https://doi.org/10.1016/j.jesp.2019.103828

Landau, M. J., Meier, B. P., & Keefer, L. A. (2010). A metaphor-enriched social cognition. *Psychological Bulletin*, *136*(6), 1045–1067. https://doi.org/10.1037/a0020970

Landau, M. J., Oyserman, D., Keefer, L. A., & Smith, G. C. (2014). The college journey and academic engagement: How metaphor use enhances identity-based motivation. In *Journal of Personality and Social Psychology* (Vol. 106, Issue 5, pp. 679–698). American Psychological Association. https://doi.org/10.1037/a0036414

Langton, S. R. H. (2000). The mutual influence of gaze and head orientation in the analysis of social attention direction. *The Quarterly Journal of Experimental Psychology Section A*, *53*(3), 825–845. https://doi.org/10.1080/713755908

Langton, S. R. H., & Bruce, V. (2000). You must see the point: Automatic processing of cues to the direction of social attention. In *Journal of Experimental Psychology: Human Perception and Performance* (Vol. 26, Issue 2, pp. 747–757). American Psychological Association. https://doi.org/10.1037/0096-1523.26.2.747

Laponce, J. A. (1983). Left and Right: The Topography of Political Perceptions. *The Journal of Politics*, *45*(4), 1044–1045. https://doi.org/10.2307/2130427

Lee, S. W. S., & Schwarz, N. (2010). Dirty hands and dirty mouths: Embodiment of the moral-purity metaphor is specific to the motor modality involved in moral transgression. *Psychological Science*, *21*(10), 1423–1425. https://doi.org/10.1177/0956797610382788

Logan, G. D. (1995). Linguistic and conceptual control of visual spatial attention. *Cognitive Psychology*, *28*(2), 103–174. https://doi.org/10.1006/cogp.1995.1004

Lukes, S. (1973). *Individualism*. Basil Blackwell.

Maass, A., Pagani, D., & Berta, E. (2007). How beautiful is the goal and how violent is the fistfight? Spatial bias in the interpretation of human behavior. *Social Cognition*, *25*(6), 833–852. https://doi.org/10.1521/soco.2007.25.6.833

Maass, A., & Russo, A. (2003). Directional bias in the mental representation of spatial events: Nature or culture? *Psychological Science*, *14*(4), 296–301. https://doi.org/10.1111/1467-9280.14421

Maass, A., Suitner, C., & Deconchy, J. P. (2014). *Living in an asymmetrical world: How writing direction affects thought and action*. Psychology Press Ltd.

Maass, A., Suitner, C., Favaretto, X., & Cignacchi, M. (2009). Groups in space: Stereotypes and the spatial agency bias. *Journal of Experimental Social Psychology*, *45*(3), 496–504. https://doi.org/10.1016/j.jesp.2009.01.004

Maass, A., Suitner, C., & Nadhmi, F. (2014). What drives the spatial agency bias? An Italian-Malagasy-Arabic comparison study. *Journal of Experimental Psychology: General*, *143*(3), 991–996. https://doi.org/10.1037/a0034989

Mahon, B. Z., & Caramazza, A. (2008). A critical look at the embodied cognition hypothesis and a new proposal for grounding conceptual content. *Journal of Physiology-Paris*, *102*(1), 59–70. https://doi.org/https://doi.org/10.1016/j.jphysparis.2008.03.004

Mandler, J. M. (1992). How to build a baby: II. Conceptual primitives. In *Psychological Review* (Vol. 99, Issue 4, pp. 587–604). American Psychological Association. https://doi.org/10.1037/0033-295X.99.4.587

Mansfield, E. M., Farroni, T., & Johnson, M. H. (2003). Does gaze perception facilitate overt orienting? *Visual Cognition*, *10*(1), 7–14. https://doi.org/10.1080/713756671

Marotta, A., Román-Caballero, R., & Lupiáñez, J. (2018). Arrows don’t look at you: Qualitatively different attentional mechanisms triggered by gaze and arrows. *Psychonomic Bulletin & Review*, *25*(6), 2254–2259. https://doi.org/10.3758/s13423-018-1457-2

Mason, M. F., Tatkow, E. P., & Macrae, C. N. (2005). The look of love: Gaze shifts and person perception. *Psychological Science*, *16*(3), 236–239. https://doi.org/10.1111/j.0956-7976.2005.00809.x

Masson, N., & Pesenti, M. (2014). Attentional bias induced by solving simple and complex addition and subtraction problems. *Quarterly Journal of Experimental Psychology*, *67*(8), 1514–1526. https://doi.org/10.1080/17470218.2014.903985

Masson, N., & Pesenti, M. (2016). Interference of lateralized distractors on arithmetic problem solving: a functional role for attention shifts in mental calculation. *Psychological Research*, *80*(4), 640–651. https://doi.org/10.1007/s00426-015-0668-7

Matlock, T., Ramscar, M., & Boroditsky, L. (2005). On the experiential link between spatial and temporal language. *Cognitive Science*, *29*(4), 655–664. https://doi.org/https://doi.org/10.1207/s15516709cog0000_17

Mayer, A. R., & Kosson, D. S. (2004). The effects of auditory and visual linguistic distractors on target localization. In *Neuropsychology* (Vol. 18, Issue 2, pp. 248–257). American Psychological Association. https://doi.org/10.1037/0894-4105.18.2.248

Mazza, V., Turatto, M., Rossi, M., & Umiltà, C. (2007). How automatic are audiovisual links in exogenous spatial attention? *Neuropsychologia*, *45*(3), 514–522. https://doi.org/https://doi.org/10.1016/j.neuropsychologia.2006.02.010

McCourt, M. E., & Jewell, G. (1999). Visuospatial attention in line bisection: Stimulusmodulation of pseudoneglect. *Neuropsychologia*, *37*(7), 843–855. https://doi.org/10.1016/S0028-3932(98)00140-7

McGlone, M. S., & Harding, J. L. (1998). Back (or forward?) to the future: The role of perspective in temporal language comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *24*(5), 1211–1223. https://doi.org/10.1037/0278-7393.24.5.1211

Mead, G. H. (1934). Mind, self, and society from the standpoint of a social behaviorist. In *Mind, Self, and Society from the Standpoint of a Social Behaviorist.* Chicago.

Meier, B. P., & Dionne, S. (2009). Downright sexy: Verticality, implicit power, and perceived physical attractiveness. *Social Cognition*, *27*(6), 883–892. https://doi.org/10.1521/soco.2009.27.6.883

Meier, B. P., Hauser, D. J., Robinson, M. D., Friesen, C. K., & Schjeldahl, K. (2007). What's "Up" With God? Vertical Space as a Representation of the Divine. *Journal of Personality and Social Psychology*, *93*(5), 699–710. https://doi.org/10.1037/0022-3514.93.5.699

Meier, B. P., & Robinson, M. D. (2004). Why the sunny side is up: Associations between affect and vertical position. *Psychological Science*, *15*(4), 243–247. https://doi.org/10.1111/j.0956-7976.2004.00659.x

Meier, B. P., & Robinson, M. D. (2006). Does "feeling down" mean seeing down? Depressive symptoms and vertical selective attention. *Journal of Research in Personality, 40*(4), 451–461. https://doi.org/https://doi.org/10.1016/j.jrp.2005.03.001

Mills, M., Smith, K. B., Hibbing, J. R., & Dodd, M. D. (2015). Obama cares about visuo-spatial attention: Perception of political figures moves attention and determines gaze direction. *Behavioural Brain Research*, *278*, 221–225. https://doi.org/10.1016/j.bbr.2014.09.048

Mio, J. S., Thompson, S. C., & Givens, G. H. (1993). The commons dilemma as metaphor: Memory, influence, and implications for environmental conservation. *Metaphor and Symbolic Activity*, *8*(1), 23–42. https://doi.org/10.1207/s15327868ms0801_2

Mischel, W., & Shoda, Y. (1998). Reconciling processing dynamics and personality dispositions. *Annual Review of Psychology*, *49*(1), 229–258. https://doi.org/10.1146/annurev.psych.49.1.229

Moeller, S. K., Robinson, M. D., & Zabelina, D. L. (2008). Personality dominance and preferential use of the vertical dimension of space: Evidence from spatial attention paradigms. *Psychological Science*, *19*(4), 355–361. https://doi.org/10.1111/j.1467-9280.2008.02093.x

Monahan, L., & Romero, M. (2020). Heading the right way? The influence of motion direction in advertising on brand trust. *Journal of Advertising*, *49*(3), 250–269. https://doi.org/10.1080/00913367.2020.1751010

Morikawa, K., & McBeath, M. K. (1992). Lateral motion bias associated with reading direction. *Vision Research*, *32*(6), 1137–1141. https://doi.org/https://doi.org/10.1016/0042-6989(92)90014-A

Müller, H. J., & Rabbitt, P. M. (1989). Reflexive and voluntary orienting of visual attention: Time course of activation and resistance to interruption. In *Journal of Experimental Psychology: Human Perception and Performance* (Vol. 15, Issue 2, pp. 315–330). American Psychological Association. https://doi.org/10.1037/0096-1523.15.2.315

Murphy, G. L. (1996). On metaphoric representation. *Cognition*, *60*(2), 173–204. https://doi.org/10.1016/0010-0277(96)00711-1

Murphy, G. L. (1997). Reasons to doubt the present evidence for metaphoric representation. In *Cognition* (Vol. 62).

Nachshon, I. (1985). Directional preferences in perception of visual stimuli. *International Journal of Neuroscience*, *25*(3–4), 161–174. https://doi.org/10.3109/00207458508985369

Nachson, I., Argaman, E., & Luria, A. (1999). Effects of directional habits and handedness on aesthetic preference for left and right profiles. *Journal of Cross-Cultural Psychology*, *30*(1), 106–114. https://doi.org/10.1177/0022022199030001006

Nazir, T. A., Ben-Boutayab, N., Decoppet, N., Deutsch, A., & Frost, R. (2004). Reading habits, perceptual learning, and recognition of printed words. *Brain and Language*, *88*(3), 294–311. https://doi.org/https://doi.org/10.1016/S0093-934X(03)00168-8

Ngo, M. K., & Spence, C. (2010). Auditory, tactile, and multisensory cues facilitate search for dynamic visual stimuli. *Attention, Perception, and Psychophysics*, *72*(6), 1654–1665. https://doi.org/10.3758/APP.72.6.1654

Niedenthal, P. M., Barsalou, L. W., Winkielman, P., Krauth-Gruber, S., & Ric, F. (2005). Embodiment in attitudes, social perception, and emotion. *Personality and Social Psychology Review*, *9*(3), 184–211. https://doi.org/10.1207/s15327957pspr0903_1

Nisbett, R. E., & Ross, L. (1980). *Human inference: Strategies and shortcomings of social judgment*. Prentice-Hall.

Nobre, A. C., Sebestyen, G. N., Gitelman, D. R., Mesulam, M. M., Frackowiak, R. S., & Frith, C. D. (1997). Functional localization of the system for visuospatial attention using positron emission tomography. *Brain*, *120*(3), 515–533. https://doi.org/10.1093/brain/120.3.515

Noland, C. (2010). *Agency and Embodiment*. Harvard University Press.

Nuerk, H.-C., Patro, K., Cress, U., Schild, U., Friedrich, C. K., & Göbel, S. M. (2015). How space-number associations may be created in preliterate children: six distinct mechanisms. *Frontiers in Psychology*, *6*, 215. https://doi.org/10.3389/fpsyg.2015.00215

Núñez, R., & Sweetser, E. (2006). With the future behind them: Convergent evidence from Aymara language and gesture in the crosslinguistic comparison of spatial construals of time. *Cognitive Science*, *30*(3), 401–450. https://doi.org/10.1207/s15516709cog0000_62

Olson, D. (1977). From utterance to text: The bias of language in speech and writing. *Harvard Educational Review*, *47*(3), 257–281. https://doi.org/10.17763/haer.47.3.8840364413869005

Oosterhof, N. N., & Todorov, A. (2008). The functional basis of face evaluation. *Proceedings of the National Academy of Sciences of the United States of America*. https://doi.org/10.1073/pnas.0805664105

Opfer, J. E., & Furlong, E. E. (2011). How numbers bias preschoolers' spatial search. *Journal of Cross-Cultural Psychology*, *42*(4), 682–695. https://doi.org/10.1177/0022022111406098

Opfer, J. E., & Thompson, C. A. (2006). Even early representations of numerical magnitude are spatially organized: Evidence for a directional magnitude bias in pre-reading preschoolers. *Proceedings of the Annual Meeting of the Cognitive Science Society*, *28*(28).

Oppenheimer, D. M., & Trail, T. E. (2010). Why leaning to the left makes you lean to the left: Effect of spatial orientation on political attitudes. *Social Cognition*, *28*(5), 651–661. https://doi.org/10.1521/soco.2010.28.5.651

Ortiz, M. J. (2011). Primary metaphors and monomodal visual metaphors. *Journal of Pragmatics*, *43*(6), 1568–1580. https://doi.org/https://doi.org/10.1016/j.pragma.2010.12.003

Ortony, A. (1975). Why metaphors are necessary and not just nice. *Educational Theory*, *25*(1), 45–53. https://doi.org/10.1111/j.1741-5446.1975.tb00666.x

Osborn, M. (1967). Archetypal metaphor in rhetoric: The light-dark family. *Quarterly Journal of Speech*, *53*(2), 115–126. https://doi.org/10.1080/00335636709382823

Ossandón, J. P., Onat, S., & König, P. (2014). Spatial biases in viewing behavior. *Journal of Vision*, *14*(2), 1–26. https://doi.org/10.1167/14.2.20

Ouellet, M., Santiago, J., Funes, M. J., & Lupiáñez, J. (2010). Thinking about the future moves attention to the right. *Journal of Experimental Psychology: Human Perception and Performance*, *36*(1), 17–24. https://doi.org/10.1037/a0017176

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (2010). Is the future the right time? *Experimental Psychology*, *57*(4), 308–314. https://doi.org/10.1027/1618-3169/a000036

Padakannaya, P., Devi, M. L., Zaveria, B., Chengappa, S. K., & Vaid, J. (2002). Directional scanning effect and strength of reading habit in picture naming and recall. In *Brain and Cognition* (Vol. 48, Issues 2–3, pp. 484–490). Elsevier Science.

Paladino, M.-P., & Castelli, L. (2008). On the immediate consequences of intergroup categorization: Activation of approach and avoidance motor behavior toward ingroup and outgroup members. *Personality and Social Psychology Bulletin*, *34*(6), 755–768. https://doi.org/10.1177/0146167208315155

Palanica, A., & Itier, R. J. (2011). Searching for a perceived gaze direction using eye tracking. *Journal of Vision*, *11*(2), 19. https://doi.org/10.1167/11.2.19

Parsons, T. (1968). *The Structure of Social Action*. Free Press.

Patro, K., Fischer, U., Nuerk, H.-C., & Cress, U. (2016). How to rapidly construct a spatial–numerical representation in preliterate children (at least temporarily). *Developmental Science*, *19*(1), 126–144. https://doi.org/https://doi.org/10.1111/desc.12296

Patro, K., Nuerk, H.-C., & Cress, U. (2016). Mental number line in the preliterate brain: The role of early directional experiences. *Child Development Perspectives*, *10*(3), 172–177. https://doi.org/https://doi.org/10.1111/cdep.12179

Patterson, K. J. (2016). The analysis of metaphor: To what extent can the theory of lexical priming help our understanding of metaphor usage and comprehension? *Journal of Psycholinguistic Research*, *45*(2), 237–258. https://doi.org/10.1007/s10936-014-9343-1

Pearson, P. D., Raphael, T. E., Tepaske, N., & Hyser, C. (1981). The function of metaphor in children's recall of expository passages. *Journal of Reading Behavior*, *13*(3), 249–261. https://doi.org/10.1080/10862968109547412

Perrett, D. I., Harries, M. H., Mistlin, A. J., Hietanen, J. K., & Al, E. (1990). Social signals analyzed at the single cell level: Someone is looking at me, something touched me, something moved! *International Journal of Comparative Psychology*, *4*(1), 25–55.

Perrott, D. A., Genter, D., & Bodenhausen, G. V. (2005). Resistance is futile: The unwitting insertion of analogical inferences in memory. *Psychonomic Bulletin & Review*, *12*(4), 696–702. https://doi.org/10.3758/BF03196760

Piaget, J., & Inhelder, B. (1969). *The Psychology of the Child*. Basic Books.

Pinhas, M., Shaki, S., & Fischer, M. H. (2014). Heed the signs: Operation signs have spatial associations. *Quarterly Journal of Experimental Psychology*, *67*(8), 1527–1540. https://doi.org/10.1080/17470218.2014.892516

Pinker, S. (2007). Toward a consilient study of literature. *Philosophy and Literature*, *31*(1), 162–178.

Pollatsek, A., Bolozky, S., Well, A. D., & Rayner, K. (1981). Asymmetries in the perceptual span for Israeli readers. *Brain and Language*, *14*(1), 174–180. https://doi.org/10.1016/0093-934X(81)90073-0

Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology*, *32*(1), 3–25. https://doi.org/10.1080/00335558008248231

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. *Attention and Performance*. https://doi.org/10.1162/jocn.1991.3.4.335

Posner, M. I., Rafal, R. D., Choate, L. S., & Vaughan, J. (1985). Inhibition of return: Neural basis and function. *Cognitive Neuropsychology*, *2*(3), 211–228. https://doi.org/10.1080/02643298508252866

Posner, M. I., & Snyder, C. R. (1975). Facilitation and inhibition in the processing of signals. In P. M. Rabbitt & S. Dornic (Eds.), *Attention and Performance* (pp. 669–682). Academic Press.

Pratt, J., & Hommel, B. (2003). Symbolic control of visual attention: The role of working memory and attentional control settings. In *Journal of Experimental Psychology: Human Perception and Performance* (Vol. 29, Issue 5, pp. 835–845). American Psychological Association. https://doi.org/10.1037/0096-1523.29.5.835

Pratt, J., Spalek, T. M., & Bradshaw, F. (1999). The time to detect targets at inhibited and noninhibited locations: Preliminary evidence for attentional momentum. *Journal of Experimental Psychology: Human Perception and Performance*, *25*(3), 730–746. https://doi.org/10.1037/0096-1523.25.3.730

Proctor, R. W., & Cho, Y. S. (2006). Polarity correspondence: A general principle for performance of speeded binary classification tasks. *Psychological Bulletin*, *132*(3), 416–442. https://doi.org/10.1037/0033-2909.132.3.416

Regolin, L. (2006). The case of the line-bisection: When both humans and chickens wander left. In *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior* (Vol. 42, Issue 1, pp. 101–103). Masson Italia. https://doi.org/10.1016/S0010-9452(08)70330-7

Ricciardelli, P., Bricolo, E., Aglioti, S. M., & Chelazzi, L. (2002). My eyes want to look where your eyes are looking: Exploring the tendency to imitate another individual's gaze. *NeuroReport*, *13*(7), 2259–2264. https://doi.org/10.1097/00001756-200212030-00018

Richardson, D., & Matlock, T. (2007). The integration of figurative language and static depictions: An eye movement study of fictive motion. *Cognition*, *102*(1), 129–138. https://doi.org/https://doi.org/10.1016/j.cognition.2005.12.004

Rinaldi, L., Di Luca, S., Henik, A., & Girelli, L. (2014a). Reading direction shifts visuospatial attention: An interactive account of attentional biases. *Acta Psychologica*, *151*, 98–105. https://doi.org/10.1016/j.actpsy.2014.05.018

Rinaldi, L., Di Luca, S., Henik, A., & Girelli, L. (2014b). Reading direction shifts visuospatial attention: An Interactive Account of attentional biases. *Acta Psychologica*, *151*, 98–105. https://doi.org/10.1016/j.actpsy.2014.05.018

Rinck, M., & Becker, E. S. (2007). Approach and avoidance in fear of spiders. *Journal of Behavior Therapy and Experimental Psychiatry*, *38*(2), 105–120. https://doi.org/https://doi.org/10.1016/j.jbtep.2006.10.001

Riskind, J. H. (1984). They stoop to conquer: Guiding and self-regulatory functions of physical posture after success and failure. *Journal of Personality and Social Psychology*, *47*(3), 479–493. https://doi.org/10.1037/0022-3514.47.3.479

Robinson, M. D., Zabelina, D. L., Ode, S., & Moeller, S. K. (2008). The vertical nature of dominance-submission: Individual differences in vertical attention. *Journal of Research in Personality*, *42*(4), 933–948. https://doi.org/https://doi.org/10.1016/j.jrp.2007.12.002

Román, A., El Fathi, A., & Santiago, J. (2013). Spatial biases in understanding descriptions of static scenes: The role of reading and writing direction. *Memory and Cognition, 41*, 588–599. https://doi.org/10.3758/s13421-012-0285-2

Román, A., Flumini, A., & Santiago, J. (2018). Scanning of speechless comics changes spatial biases in mental model construction. *Philosophical Transactions of the Royal Society B: Biological Sciences, 373*, 20170130. https://doi.org/10.1098/rstb.2017.0130

Rosenich, E., Shaki, S., & Loetscher, T. (2020). Unstable world: Recent experience affects spatial perception. *Psychonomic Bulletin and Review*, *27*(2), 286–292. https://doi.org/10.3758/s13423-019-01703-9

Rozin, P., & Fallon, A. E. (1987). A perspective on disgust. In *Psychological Review* (Vol. 94, Issue 1, pp. 23–41). American Psychological Association. https://doi.org/10.1037/0033-295X.94.1.23

Santangelo, V., Van Der Lubbe, R. H. J., Belardinelli, M. O., & Postma, A. (2006). Spatial attention triggered by unimodal, crossmodal, and bimodal exogenous cues: A comparison of reflexive orienting mechanisms. *Experimental Brain Research*, *173*(1), 40–48. https://doi.org/10.1007/s00221-006-0361-6

Santiago, J., Lupiáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin and Review*, *14*, 512–516. https://doi.org/10.3758/BF03194099

Santiago, J., Román, A., & Ouellet, M. (2011). Flexible foundations of abstract thought: A review and a theory. In *Spatial Dimensions of Social Thought* (pp. 39–108). De Gruyter Mouton. https://doi.org/10.1515/9783110254310.39

Santiago, J., Román, A., Ouellet, M., Rodríguez, N., & Pérez-Azor, P. (2010). In hindsight, life flows from left to right. *Psychological Research*, *74*(1), 59–70. https://doi.org/10.1007/s00426-008-0220-0

Saraiva, A. C., Schueuer, F., & Bestmann, S. (2013). Emotional valence and contextual affordances flexibly shape approach-avoidance movements . In *Frontiers in Psychology*

(Vol. 4, p. 933). https://www.frontiersin.org/article/10.3389/fpsyg.2013.00933

Schmitt, M., Postma, A., & De Haan, E. (2000). Interactions between exogenous auditory and visual spatial attention. *The Quarterly Journal of Experimental Psychology Section A*, *53*(1), 105–130. https://doi.org/10.1080/713755882

Schubert, T. W. (2005). Your highness: Vertical positions as perceptual symbols of power. *Journal of Personality and Social Psychology*, *89*(1), 1–21. https://doi.org/10.1037/0022-3514.89.1.1

Schwarz, N. (2002). Feelings as information: Moods influence judgments and processing strategies. In *Heuristics and biases: The psychology of intuitive judgment.* (pp. 534–547). Cambridge University Press. https://doi.org/10.1017/CBO9780511808098.031

Scott, G. B. D. (1955). Cranial and cerebral asymmetry and handedness. *Man*, *55*, 67–70. https://doi.org/10.2307/2794838

Scott, L. M. (1994). Images in advertising: The need for a theory of visual rhetoric. *Journal of Consumer Research*, *21*(2), 252. https://doi.org/10.1086/209396

Selcon, S. J., Taylor, R. M., & McKenna, F. P. (1995). Integrating multiple information sources: Using redundancy in the design of warnings. *Ergonomics*, *38*(11), 2362–2370. https://doi.org/10.1080/00140139508925273

Semin, G. R., & Cacioppo, J. T. (2009). From embodied representation to co-regulation. In *Mirror neuron systems: The Role of Mirroring Processes in Social Cognition.* (pp. 107–120). Humana Press/Springer Nature.

Semin, G. R., & Smith, E. R. (2002). Interfaces of social psychology with situated and embodied cognition. *Cognitive Systems Research*, *3*(3), 385–396. https://doi.org/https://doi.org/10.1016/S1389-0417(02)00049-9

Semin, G. R., & Smith, E. R. (2008). Embodied grounding: Social, cognitive, affective, and neuroscientific approaches. In Gün R Semin & E. R. Smith (Eds.), *Embodied grounding: Social, cognitive, affective, and neuroscientific approaches.* Cambridge University Press. https://doi.org/10.1017/CBO9780511805837

Shaki, S., Fischer, M. H., & Göbel, S. M. (2012). Direction counts: A comparative study of spatially directional counting biases in cultures with different reading directions. *Journal of Experimental Child Psychology*, *112*(2), 275–281. https://doi.org/https://doi.org/10.1016/j.jecp.2011.12.005

Shepperd, J. A., & Strathman, A. J. (1989). Attractiveness and height: The role of stature in dating preference, frequency of dating, and perceptions of attractiveness. *Personality and Social Psychology Bulletin*, *15*(4), 617–627. https://doi.org/10.1177/0146167289154014

Sherman, G. D., & Clore, G. L. (2009). The color of sin: White and black are perceptual symbols of moral purity and pollution. *Psychological Science*, *20*(8), 1019–1025. https://doi.org/10.1111/j.1467-9280.2009.02403.x

Siegler, R. S., & Opfer, J. E. (2003). The development of numerical estimation: Evidence for multiple representations of numerical quantity. *Psychological Science*, *14*(3), 237–250. https://doi.org/10.1111/1467-9280.02438

Simmons, W. K., & Barsalou, L. W. (2003). The similarity-in-topography principle: Reconciling theories of conceptual deficits. *Cognitive Neuropsychology*, *20*(3–6), 451–486. https://doi.org/10.1080/02643290342000032

Smith, E. R. (1992). The role of exemplars in social judgment. In *The construction of social judgments.* (pp. 107–132). Lawrence Erlbaum Associates, Inc.

Smith, E. R., & Semin, G. R. (2007). Situated social cognition. *Current Directions in Psychological Science*, *16*(3), 132–135. https://doi.org/10.1111/j.1467-8721.2007.00490.x

Solarz, A. K. (1960). Latency of instrumental responses as a function of compatibility with the meaning of eliciting verbal signs. *Journal of Experimental Psychology*, *59*(4), 239–245. https://doi.org/10.1037/h0047274

Spalek, T. M., & Hammad, S. (2004). Supporting the attentional momentum view of IOR: Is attention biased to go right? *Perception and Psychophysics*, *66*, 219–233. https://doi.org/10.3758/BF03194874

Spalek, T. M., & Hammad, S. (2005). The left-to-right bias in inhibition of return is due to the direction of reading. *Psychological Science*, *16*(1), 15–18. https://doi.org/10.1111/j.0956-7976.2005.00774.x

Spence, C., & Driver, J. (1994). Covert spatial orienting in audition: Exogenous and endogenous mechanisms. *Journal of Experimental Psychology: Human Perception and Performance*, *20*(3), 555–574. https://doi.org/10.1037/0096-1523.20.3.555

Spence, C., & Driver, J. (1997). Audiovisual links in exogenous covert spatial orienting. *Perception and Psychophysics*, *59*(1), 1–22. https://doi.org/10.3758/BF03206843

Spence, C., & McGlone, F. P. (2001). Reflexive spatial orienting of tactile attention. *Experimental Brain Research*, *141*(3), 324–330. https://doi.org/10.1007/s002210100883

Spence, C., McGlone, F. P., Kettenmann, B., & Kobal, G. (2001). Attention to olfaction. *Experimental Brain Research*, *138*(4), 432–437. https://doi.org/10.1007/s002210100713

Spence, C., Parise, C., & Chen, Y. C. (2011). The Colavita visual dominance effect. In J. J. McDonald, J. J. Green, V. Störmer, & S. A. Hillyard (Eds.), *The Neural Bases of Multisensory Processes* (pp. 529–556). CRC Press/Taylor & Francis. https://doi.org/10.1201/b11092-34

Spencer, S. J., Logel, C., & Davies, P. G. (2016). Stereotype threat. *Annual Review of Psychology*, *67*(1), 415–437. https://doi.org/10.1146/annurev-psych-073115-103235

Spivey, M. J., & Geng, J. J. (2001). Oculomotor mechanisms activated by imagery and memory: eye movements to absent objects. *Psychological Research*, *65*(4), 235–241. https://doi.org/10.1007/s004260100059

Strack, F., Martin, L. L., & Stepper, S. (1988). Inhibiting and facilitating conditions of the human smile: A nonobtrusive test of the facial feedback hypothesis. In *Journal of Personality and Social Psychology* (Vol. 54, Issue 5, pp. 768–777). American Psychological Association. https://doi.org/10.1037/0022-3514.54.5.768

Suitner, C., & Maass, A. (2016). Spatial agency bias: Representing people in space. *Advances in Experimental Social Psychology*, *53*, 245–301. https://doi.org/10.1016/bs.aesp.2015.09.004

Suitner, C., Maass, A., & Ronconi, L. (2017). From spatial to social asymmetry: Spontaneous and conditioned associations of gender and space. *Psychology of Women Quarterly*, *41*(1), 46–64. https://doi.org/10.1177/0361684316676045

Suitner, C., & McManus, I. C. (2011). Aesthetic asymmetries, spatial agency, and art history: A social psychological perspective. In T. Schubert & A. Maass (Eds.), *Spatial Dimensions of Social Thought* (pp. 277–302). De Gruyter Mouton.

Thibodeau, P. H., & Boroditsky, L. (2011). Metaphors we think with: The role of metaphor in reasoning. *PloS One*, *6*(2), e16782. https://doi.org/10.1371/journal.pone.0016782

Thibodeau, P. H., Hendricks, R. K., & Boroditsky, L. (2017). How linguistic metaphor scaffolds reasoning. In *Trends in Cognitive Sciences* (Vol. 21, Issue 11, pp. 852–863). Elsevier Science. https://doi.org/10.1016/j.tics.2017.07.001

Tipples, J. (2008). Orienting to counterpredictive gaze and arrow cues. *Perception & Psychophysics*, *70*(1), 77–87. https://doi.org/10.3758/PP.70.1.77

Tomasello, M., & Call, J. (1997). *Primate Cognition*. Oxford University Press.

Toronchuk, J. A., & Ellis, G. F. R. (2007). Disgust: Sensory affect or primary emotional system? *Cognition and Emotion*, *21*(8), 1799–1818. https://doi.org/10.1080/02699930701298515

Torralbo, A., Santiago, J., & Lupiáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science*, *30*(4), 745–757. https://doi.org/10.1207/s15516709cog0000_67

Tse, P. U., & Cavanagh, P. (2000). Chinese and Americans see opposite apparent motions in a Chinese character. *Cognition*, *74*(3), B27–B32. https://doi.org/https://doi.org/10.1016/S0010-0277(99)00065-7

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology*, *23*(4), 515–557. https://doi.org/10.1016/0010-0285(91)90005-9

Vaid, J. (2011). Asymmetries in representational drawing: Alternatives to a laterality account. In T. Schubert & A. Maass (Eds.), *Spatial Dimensions of Social Thought* (pp. 231–255). De Gruyter Mouton.

Vaid, J., & Singh, M. (1989). Asymmetries in the perception of facial affect: Is there an influence of reading habits? *Neuropsychologia*, *27*(10), 1277–1287. https://doi.org/10.1016/0028-3932(89)90040-7

Vaid, J., Singh, M., Sakhuja, T., & Gupta, G. C. (2002). Stroke direction asymmetry in figure drawing: Influence of handedness and reading/writing habits. *Brain and Cognition*, *48*(2–3), 597–602. https://doi.org/10.1006/brcg.2001.1424

Vallesi, A., McIntosh, A. R., & Stuss, D. T. (2011). How time modulates spatial responses. *Cortex*, *47*(2), 148–156. https://doi.org/https://doi.org/10.1016/j.cortex.2009.09.005

Van der Burg, E., Olivers, C. N. L., Bronkhorst, A. W., & Theeuwes, J. (2008). Pip and pop: Nonspatial auditory signals improve spatial visual search. *Journal of Experimental Psychology: Human Perception and Performance*, *34*(5), 1053–1065. https://doi.org/10.1037/0096-1523.34.5.1053

Van der Burg, E., Olivers, C. N. L., Bronkhorst, A. W., & Theeuwes, J. (2009). Poke and pop: Tactile–visual synchrony increases visual saliency. *Neuroscience Letters*, *450*(1), 60–64. https://doi.org/https://doi.org/10.1016/j.neulet.2008.11.002

van Elk, M., van Schie, H. T., & Bekkering, H. (2010). From left to right: Processing acronyms referring to names of political parties activates spatial associations. *Quarterly Journal of*

Experimental Psychology, *63*(11), 2202–2219. https://doi.org/10.1080/17470218.2010.495160

Vendetti, M. S., Wu, A., Rowshanshad, E., Knowlton, B. J., & Holyoak, K. J. (2014). When reasoning modifies memory: schematic assimilation triggered by analogical mapping. *Journal of Experimental Psychology. Learning, Memory, and Cognition*, *40*(4), 1172–1180. https://doi.org/10.1037/a0036350

von Hecker, U., Klauer, K. C., Wolf, L., & Fazilat-Pour, M. (2016). Spatial processes in linear ordering. *Journal of Experimental Psychology: Learning Memory and Cognition*, *42*(7), 1003–1033. https://doi.org/10.1037/xlm0000220

Wallace, M. T., Meredith, M. A., & Stein, B. E. (1998). Multisensory integration in the superior colliculus of the alert cat. *Journal of Neurophysiology*, *80*(2), 1006–1010. https://doi.org/10.1152/jn.1998.80.2.1006

Ward, L. M. (1994). Supramodal and modality-specific mechanisms for stimulus-driven shifts of auditory and visual attention. *Canadian Journal of Experimental Psychology = Revue Canadienne de Psychologie Expérimentale*, *48*(2), 242–259. https://doi.org/10.1037/1196-1961.48.2.242

Ward, L. M., McDonald, J. J., & Golestani, N. (1998). Cross-modal control of attention shifts. In R. D. Wright (Ed.), *Vancouver studies in cognitive science* (Vol. 8, pp. 232–268). Oxford University Press. https://psycnet.apa.org/record/1999-02040-009

Ward, L. M., McDonald, J. J., & Lin, D. (2000). On asymmetries in cross-modal spatial attention orienting. *Perception and Psychophysics*, *62*(6), 1258–1264. https://doi.org/10.3758/BF03212127

Weger, U. W., & Pratt, J. (2008). Time flies like an arrow: Space-time compatibility effects suggest the use of a mental timeline. *Psychonomic Bulletin and Review*, *15*(2), 426–430. https://doi.org/10.3758/PBR.15.2.426

Wells, G. L., & Petty, R. E. (1980). The effects of over head movements on persuasion: Compatibility and incompatibility of responses. *Basic and Applied Social Psychology*, *1*(3), 219–230. https://doi.org/10.1207/s15324834basp0103_2

Wertheimer, M. (2010). A Gestalt prerspective on the psychology of thinking. In Glatzeder B., Goel V., & Müller A. (Eds.), *Towards a Theory of Thinking* (pp. 49–58). Springer, Berlin, Heidelberg. https://doi.org/10.1007/978-3-642-03129-8_4

Winter, B. (2014). Horror movies and the cognitive ecology of primary metaphors. *Metaphor* *and Symbol*, *29*(3), 151–170. https://doi.org/10.1080/10926488.2014.924280

Wu, C.-C., Wick, F., & Pomplun, M. (2014). Guidance of visual attention by semantic information in real-world scenes . In *Frontiers in Psychology* (Vol. 5, p. 54). https://www.frontiersin.org/article/10.3389/fpsyg.2014.00054

y Gasset, J. O. (1951). *The Dehumanization of Art*. P. Smith.

Zhong, C.-B., & Leonardelli, G. J. (2008). Cold and lonely: Does social exclusion literally feel cold? *Psychological Science*, *19*(9), 838–842. https://doi.org/10.1111/j.1467-9280.2008.02165.x

Zhong, C.-B., & Liljenquist, K. (2006). Washing away your sins: threatened morality and physical cleansing. *Science (New York, N.Y.)*, *313*(5792), 1451–1452. https://doi.org/10.1126/science.1130726

Zwaan, R. A. (2004). The immersed experiencer: Toward an embodied theory of language comprehension. In *The Psychology of Learning and Motivation: Advances in Research and Theory, Vol. 44.* (pp. 35–62). Elsevier Science.

Zwaan, R. A., Stanfield, R. A., & Yaxley, R. H. (2002). Language comprehenders mentally represent the shapes of objects. *Psychological Science*, *13*(2), 168–171. https://doi.org/10.1111/1467-9280.00430

Zwaan, R. A., & Taylor, L. J. (2006). Seeing, acting, understanding: Motor resonance in language comprehension. In *Journal of Experimental Psychology: General* (Vol. 135, Issue 1, pp. 1–11). American Psychological Association. https://doi.org/10.1037/0096-3445.135.1.1

Zwaan, R. A., & Yaxley, R. H. (2003). Spatial iconicity affects semantic relatedness judgments. *Psychonomic Bulletin and Review*, *10*(4), 954–958. https://doi.org/10.3758/BF03196557

Zwickel, J., & Melissa, L. H. V. (2010). How the presence of persons biases eye movements. *Psychonomic Bulletin and Review*, *7*, 257–262. https://doi.org/10.3758/PBR.17.2.257

Chapter II.

Social inferences from faces as a function of the left-to-right movement continuum

Chapter based on:

Mendonça, R., Garrido, M. V., & Semin, G. R. (2020). Social inferences from faces as a function of the left-to-right movement continuum. *Frontiers in Psychology, section Personality and Social Psychology*, *11*, 1488. https://doi.org/10.3389/fpsyg.2020.01488

Open Science Framework: osf.io/v5jpd

Abstract

We examined whether reading and writing habits known to drive agency perception also shape the attribution of other agency-related traits, particularly for faces oriented congruently with script direction (i.e., left-to-right). Participants rated front-oriented, left-oriented and right-oriented faces on 14 dimensions. These ratings were first reduced to two dimensions, which were further confirmed with a new sample: power and social-warmth. Both dimensions were systematically affected by head orientation. Right-oriented faces generated a stronger endorsement of the power dimension (e.g., agency, dominance), and, to a lesser extent, of the social-warmth dimension, relative to the left and frontal-oriented faces. A further interaction between the head orientation of the faces and their gender revealed that front-facing females, relative to front-facing males, were attributed higher social-warmth scores, or communal traits (e.g., valence, warmth). These results carry implications for the representation of people in space particularly in marketing and political contexts. Face stimuli and respective norming data are available at www.osf.io/v5jpd.

Keywords

Face Perception; Social Inferences; Head Orientation; Eye Gaze; Face Database

Introduction

The wealth of information carried by faces may appear to pose a formidable processing task. Nevertheless, people have the remarkable ability to perceive, recognize, memorize and judge faces (Sato & Yoshikawa, 2013) fairly accurately in a matter of milliseconds (Willis & Todorov, 2006). For instance, the rapid attribution of traits to facial stimuli correlates well with actual self-judgments of personality (Penton-Voak et al., 2006). Such convergence alone (among other sources of evidence) attests to the potential of studying human faces in psychology.

Because humans are equipped with a specialized neural network for processing face stimuli they are particularly good at attending to eye gaze in faces (Allison et al., 2000; Hoffman & Haxby, 2000; Hooker et al., 2003). Given their biological and social relevance, human faces are detected and recognized faster than those of primates (Simpson et al., 2014). In fact, the white sclera surrounding the iris is distinct among primates and facilitates the understanding of where another is looking at (Emery, 2000; Kobayashi & Kohshima, 2001). Eye-gaze, whether direct or averted, has been shown to preferentially capture and engage our attention for distinct reasons (Palanica & Itier, 2012). Direct eye-gaze signals readiness for social interaction, provides a medium for nonverbal communication (Csibra & Gergely, 2009) and for the recognition of certain emotional expressions such as anger (Adams & Kleck, 2003). On the other hand, averted gaze is evolutionarily-charged as it may indicate changes in the surrounding environment (Anderson et al., 2003) and activates avoidance motivational brain systems (Hietanen et al., 2008). Because it informs the observer about possible environmental threats, averted gaze triggers automatic shifts of visual attention in the gazed-at direction which is assumed to be of interest to the observer (Driver et al., 1999; Friesen & Kingstone, 1998; Frischen et al., 2007; Hietanen, 1999). This lateralized orientation of social attention is particularly prominent when observing rightward facing gazes due to a cultural asymmetry in visual scanning shaped by the reading and writing habits in Western countries (left-to-right, Suitner et al., 2017). These scanning habits congruently ground the direction in which we conceive human movement, or agency.

The current study was designed to further examine how faces gazing to the left and the right capture attention and whether gaze directionality influences different social inferences. The expectation is that rightward faces, which are consistent with the left-to-right script direction of the participants, will be assigned more agency and agentic-related social inferences than the remaining face directionalities. In the following, we present a brief review of a visual scanning bias - ‘spatial agency bias’ (SAB, for a review see Suitner & Maass, 2016), its foundations and the main findings that its research has generated. Subsequently, we refer to the literature that draws the implications of SAB for social inferences correlated with agency. Finally, we provide an overview of the current research.

Action is represented as unfolding laterally in the direction of how a native language's script is written and the direction in which we read. This is also correlated with the syntactic order in a sentence - with the agent (subject) preceding the 'patient', namely the 'object' of the action (Maass et al., 2014). These overlapping regularities are reinforced through repeated exposure to spatial layouts in everyday life which are coherent with script direction. Consequently, mental representations of human action are envisaged along a trajectory that correlates with the reading and writing direction along with the syntactical structure of the language one is socialized in. Thus, action progresses from left-to-right in languages such as English and French and right-to-left in languages such as Arabic and Hebrew, and the agent of the action typically occupies the left or right position, respectively, in spatial representations (Maass & Russo, 2003; Stroustrup & Wallentin, 2018; Wallentin et al., 2019).

These spatial biases are also known to influence other important aspects of social life such as artwork appreciation as well as perceptions of sport events. For example, Maass and colleagues (2007) found that Italian participants perceived a goal in football as more beautiful and stronger and a boxing scene as more violent and harmful, when the direction of action was presented as moving from left-to-right rather than the reverse. Interestingly, these results were found to reverse for Arabic speaking participants.

The systematic link between gender stereotyping and spatial imaging was first shown by Chatterjee (2002; Chatterjee, Southwood, & Basilico, 1999). He reported that men are typically portrayed facing right to convey higher agency, a basic dimension stereotypically associated with males (Abele, 2003). Females, however, are predominantly represented facing left. The asymmetrical rightward bias also facilitates gender categorization. Male, relative to female faces, are categorized faster when their profile is presented facing right (Suitner et al., 2017). The spatial representation of stereotypically agentic groups (e.g., males, young people) also follows the culturally determined script direction. In Western countries agentic groups are systematically placed to the left of groups with less agentic qualities (e.g., females, old people) (Abele & Wojciszke, 2014; Maass et al., 2009).

Importantly, these horizontal asymmetries have numerous implications for person perception and are likely to shape social judgments (Maass et al., 2007). Notably, when judging someone as agentic, by association, we often endow them with additional qualities such as power, dominance, competitiveness, and ambition (Hitlin & Elder, 2007). Indeed, in different research traditions with different approaches, the same attributes often emerge with converging patterns of results (Abele, 2003; Fiske et al., 2002; Oosterhof & Todorov, 2008).

For example, Fiske and colleagues (Fiske et al., 2002) have proposed that group stereotypes are captured by two primary dimensions namely warmth and competence. A similar proposal by Oosterhof and Todorov (Oosterhof & Todorov, 2008) suggests that two dimensions account for multiple trait inferences drawn from emotionally neutral faces. These are the valence component, comprising of trait judgments such as attractiveness and responsibility and a dominance component comprising of judgments such as aggressiveness, dominance, and confidence. These dimensions are semantically and functionally convergent with those proposed by Fiske and colleagues (Fiske et al., 2002) as well as with other authors before them (communion and agency, Bakan, 1995; e.g., affiliation and dominance, Wiggins, 1979).

Although people rely on numerous traits when evaluating faces, these are correlated with each other and appear to be summed in two fundamental dimensions, which relate to the appraisal of threat (Oosterhof & Todorov, 2008). One dimension is generally informative of others' positive or negative intent and the other communicates strength and the diligence to pursue these intentions. Agentic-related traits (e.g., active, industrious) are likely to fall into the latter dimension, as they relate to the ability to dynamically implement and achieve one's goals. Evidently, there are marked differences in the attribution of these two fundamental dimensions across males and females. Men are systematically perceived as more dominant and agentic, whereas women are often endowed with communal-related traits (Abele, 2003).

Despite the evidence pointing to the convergence of dominance and agency-related traits on the same dimension employed for face evaluation, there is, to our knowledge, no study that has directly examined whether the reported bias in agency attributions generalizes to other important social properties. This was the main goal of the current study.

The aim of the study reported here was to examine the types of social inferences that are likely to be shaped by face and gaze orientation (left, frontal, right). To this end, we integrated a range of adjectives as possible inference categories that have been used: (a) in research documenting the spatial agency bias (Maass et al., 2009; Suitner et al., 2017); (b) in research showing the two-dimensional reduction from trait judgments of faces (Oosterhof & Todorov, 2008; Walker & Vetter, 2009); (c) in recent impression formation literature yielding a two-dimensional solution (Fiske et al., 2007) comparable to research on trait judgments of faces; (d) in other face perception studies (Garcia-Marques et al., 2004; Garrido et al., 2017; Langner et al., 2010; Ma et al., 2015; O'Reilly et al., 2016) and finally, (e) in research showing the grounding of abstract categories of time and politics in a horizontal left-to-right dimension (Farias et al., 2013, 2016; Lakens et al., 2011; Santiago et al., 2007).

A careful examination of these diverse but converging literatures led to the selection of 14 trait categories: attractiveness, familiarity, emotion, valence, activity/passivity, strength, speed, trustworthiness, dominance, competence, warmth, agency, temporal and ideological orientation. To examine how social inferences on these categories would be affected as a function of the head orientation we proceeded in three-steps. First, we conducted an exploratory factor analysis (EFA) to determine the minimum number of common *factors* required to adequately reproduce the fourteen trait categories. In a second step, we performed a confirmatory factor analysis (CFA) on a distinct independent sample to establish the reduction of the fourteen categories to a two-factor structure suggested in the EFA. Finally, and to address the main goal of this research, we analyzed how a target person's face would be rated on the two established dimensions as a function of head orientation (left vs. front vs. right), the target's gender (male vs. female), as well as the participants' gender (male vs. female).

We expected the dimension encompassing agency perceptions, along with other traits loading highly on this dimension (e.g., dominance, strength), to be systematically affected by head orientation. Specifically, right-oriented target faces would lead to a stronger endorsement of the agency related dimension relative to the left-oriented target faces, with front orientation taking intermediary values. Moreover, we expected an influence of the target gender on judgments related to this dimension namely that male targets would be judged higher on this dimension than female targets. Consistent with prior literature reporting that two dimensions suffice to capture trait inferences and intentions (threatening or otherwise) from faces of conspecifics, we expected the emergence of a 'softer' second dimension typified with categories such as emotion, valence, or trustworthiness. Congruent with a range of earlier findings (Cuddy et al., 2009; Prentice & Carranza, 2002; Wiggins, 1979; Wojciszke, 1994), we anticipated target gender to show systematic effects on this second dimension with female targets obtaining higher scores on communal-related traits.

Exploratory Factor Analysis

In order to investigate the underlying structure of the set of fourteen trait categories mentioned above, we conducted a preliminary exploratory factor analysis.

Materials and Methods

Bellow we report how we determined our sample size, all data exclusions (if any), all manipulations, and all measures in the study.

Participants

A total of 223 Portuguese speaking participants (166 female; M_{age} = 22.11; SD = 13.92) recruited through Prolific Academic crowdsourcing platform answered an online survey using Qualtrics Research Suite Software. The sample size was determined based on at least 50 evaluations per target photo (n = 43 models). Since each participant evaluated ten randomly selected target photos, the sample size was set to 215. Because data collection was set to stop at the end of the day the sample reached the required number of participants, the sample was slightly larger.

Materials

A carefully developed face set comprising 43 models (22 female; M_{age}= 20.98, SD = 2.26) displaying the three head orientations (left-facing, front-facing, right-facing) (see Figure 1) was used as stimulus materials (for details regarding the development of the stimuli set see Supplementary Material [SM] p. 111).

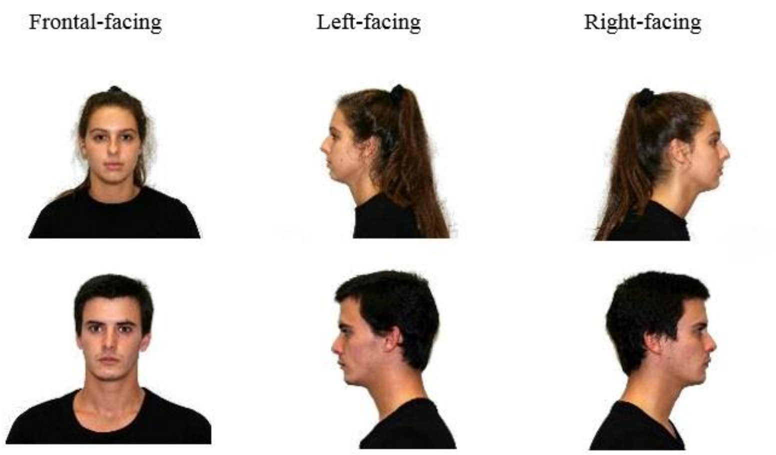

Figure 1. Sample stimuli included in the dataset.

Procedure and Measures

The total set of 129 photos (43 models x 3 head orientations) was used in the study. To prevent demotivation and keep the study relatively short, each participant was asked to rate only 10 randomly chosen models from the database. Due to a randomization issue in the survey program, some participants rated less than 10 photos. Nevertheless, each model obtained a minimum of 38 evaluations. A given target model was only presented once in one of the three head orientations to each participant. This manipulation allowed us to rule out possible interference effects such as familiarity with the stimuli.

The study has received full ethics clearance from the Ethics Committee of the host institution. All participants provided informed consent on the first page of the survey and were free to withdraw at any point in time. First, the instructions of the task and a description of the 14 items and scale endpoints were presented. Participants then evaluated a subset of ten random photos on the 14 scales without any time limit. For each photo, the respective rating item was shown below the image (e.g., "Dominance") and the corresponding scale anchors were displayed below it. The same photo appeared until the 14 scales were rated. Then a new photo-scale pair was presented, and so on. Photos and items were randomly presented.

Dimensions of Interest

Subjective ratings of the 14 dimensions were collected in 7-point scales (see Table 1).[1]

Table 1. Scales and endpoints presented in the survey.

Scales	**Endpoints**	
	1	**7**
Attractiveness	Very unattractive	Very attractive
Familiarity	Not familiar at all	Very familiar
Emotion	Does not display any emotion	Displays a lot of emotion
Valence	Very negative	Very positive
Activity/Passivity	Very passive	Very active
Strength	Very weak	Very strong
Speed	Very slow	Very fast
Trustworthiness	Not trustworthy at all	Very trustworthy
Dominance	Not dominant at all	Very dominant
Competence	Not competent at all	Very competent
Warmth	Very cold	Very warm
Agency	Not proactive at all	Very proactive
Temporal Orientation	Very past oriented	Very future oriented
Ideological Orientation	Very conservative	Very progressive

Results

Data were collected for all 129 photos. All participants responded to the entire set of scales in each subset of ten photos leaving no missing data. Additionally, we checked participants' ratings and found no indication of systematic use of the same value of the 7-point scale, therefore no responses were excluded.

In order to test for participants' ratings across the 14 scales, we split the total number of responses in two subsamples of similar size (n_1 = 949; n_2 = 904) randomly selected from the main sample and found no significant differences between the subsamples, all *t*s < 1.

[1] The full stimulus set and respective descriptive data are available on Open Science Framework; www.osf.io/v5jpd

We started by submitting the 14 scales to an EFA using principal components extraction with direct oblimin rotation. In order to further establish reliability, we conducted the analysis by having the data file randomly split into two halves. In both analyses, a similar two-factor solution emerged (for details see SM p. 112; Table 3). Consistency of participants' ratings proved to be reliable and we proceeded with a principal component analysis for the entire dataset, which resulted in a two-factor solution explaining 53.08% of the total variance. Scales of activity/passivity, strength, dominance, agency, speed, temporal orientation, and ideological orientation loaded highly on Factor 1. Scales of attractiveness, familiarity, emotion, valence, trustworthiness, and warmth loaded highly on Factor 2. Interestingly, competence was found to have a similar contribution to both factors (for details see SM p. 113; Table 4).

Confirmatory Factor Analysis

Before assessing the main hypothesis driving this research, we performed a CFA on an independent sample to verify whether the proposed two-factor structure identified in the EFA presented an adequate fit.

Materials and Methods

Participants

We recruited 360 participants (121 female, M_{age} = 22, SD_{age} = 5.39) through Prolific Academic crowdsourcing platform to participate in the online survey programmed in Qualtrics Research Suite Software. Participants were screened for Portuguese nationality and Portuguese as native language. Sample size was determined based on the following rationale: each participant was assigned to a block of 10 (*n* = 3 blocks) or 11 (*n* = 9 blocks) randomly selected photos from the entire set (*n* = 129) until each block had been rated by 30 participants. Each of the 129 photos was rated in the 14 dimensions by 30 participants.

Procedure and Measures

The procedure and dimensions of interest for the online data collection were a replication of those employed in the EFA. Participants gave their informed consent stating that their responses would be anonymous and that they could stop the survey at any time by closing the browser window. Participants rated a set of either 10 or 11 randomly selected photos in distinct face orientations. Notably, we established quotas to ensure that each stimulus photo in the three head orientations was presented to different participants. Thus, a given participant never rated the same model with different head orientations. This means that each model (*n* =

43) was evaluated 90 times in the 14 dimensions, 30 in each face orientation. Photos were presented individually and paired with a given dimension and its scale anchors until all 14 dimensions were presented. After the 14 ratings, a new photo-dimension appeared and so on. Participants had no time constraints to respond to each question, but a time-limit (40 min.) was established to complete the entire survey. Photos and items were randomly presented.

Results

We conducted a CFA with maximum likelihood estimation using AMOS 26. We did not detect any systematic use of the same scale points and there were no missing responses thus no participant was excluded. Importantly, the competence item had obtained an equivalent contribution to both factors in the EFA. Competence has conventionally been treated in previous two-dimensional models as part of the dominance/power trait judgements (Oosterhof & Todorov, 2008). We therefore included competence in Factor 1 of our proposed model (Model 1, for details see SM p. 114, Figure 4) but have nevertheless tested an alternative model with the competence item loading on Factor 2 (Model 2, for details see SM, p. 115, Figure 5). The alternative model rendered poorer adjustment indexes and thus we proceeded with the analysis for the Model 1.

Factor loadings in the new sample were smaller than those obtained in the sample used in the EFA. Notwithstanding, we replicated the same dual structure with all items loading above 0.30 (Hair et al., 2014) on the corresponding construct and being statistically significant in the predicted directions (p < .001). The two-factor model had a model chi-square of 703.387 (df = 72, p < .001). The model chi-square fit index is very sensitive to sample size and is no longer considered as a basis for acceptance or rejection (Vandenberg, 2006) because “its sensitivity to discrepancies from expected values at increasing sample sizes can be highly problematic if those discrepancies are considered trivial from an explanatory-theory perspective" (Barrett, 2007). Considering that we have a large number of observations, we used as further goodness-of-fit indices the Tucker-Lewis index (TLI = .90), the Normed Fit Index (NFI = .91), the Comparative Fit Index (CFI = .91), the Goodness of Fit Index (GFI = .97), and the Root Mean Square Error of Approximation (RMSEA = .048, *CI* [0.044, 0.051], p > .250). These values meet the recommended criteria for TLI, NFI, CFI, and GFI greater than .90 and RMSEA lower than .06 (Hu & Bentler, 1999; Marôco, 2014). Thus, the fit of the model was considered good.

The reliability of the internal scores was assessed through Mcdonald's omega, a more appropriate reliability coefficient for bifactor models than Cronbach’s alpha namely under the assumption that errors may be correlated (Raykov, 2001). Reliability was satisfactory for the power dimension (ω = .73), and below the recommended threshold for the social-warmth dimension (ω = .56) although exceeding the suggested minimum of .50 (Reise, 2012). To ensure that the individual weight of each item reflected on each latent factor, scores were saved in the original database using the regression method. Factor scores were then standardized and, attending to the nature of each set of traits, correspondingly labeled 'power' dimension (Factor 1) and 'social-warmth' dimension (Factor 2).

Subjective Rating Norms

To address the main goal driving this paper, we investigated whether face inferences regarding the two obtained dimensions of power and social-warmth are a function of the head orientation (left vs. front vs. right), the target's gender (male vs. female), as well as the participants' gender (male vs. female). To this end, we conducted a multivariate analysis of variance (MANOVA).

Significant multivariate main effects of head orientation (Pillai's trace = .029, *F* (4, 7716) = 28.267, p < .001, n_p^2 = .014) and of target gender (Pillai's trace = .007, *F* (2, 3857) = 12.637, p < .001, n_p^2 = .007) were observed. No main effect of participant's gender was observed (p > .250). A further interaction effect of head orientation and target gender emerged (Pillai's trace = .003, *F* (4, 7716) = 2.542, p = .038, n_p^2 = .001).

Subsequently, we examined the univariate main effects of head orientation and target gender, and of the interaction between the two. A significant main effect emerged across both power (*F* (2, 3858) = 49.181, p < .001, n_p^2 = .025) (see Figure 2) and social-warmth dimensions (*F* (2, 3858) = 19.913, p < .001, n_p^2 = .10) (see Figure 3). Post-hoc comparisons were performed to determine the significance of pairwise contrasts using the Bonferroni correction. In the power dimension, right-facing faces (*M* = .132, *SE* = .019) obtained significantly higher power scores than front-facing faces (*M* = -.009, *SE* = .019; p < .001, *CI* [0.077, 0.205]) and left-facing faces, which had the overall lowest power scores (*M* = -.132, *SE* = .019; p < .001, *CI* [0.200, 0.328]). Faces presented in a frontal perspective also obtained significantly higher power attributions than faces presented in a leftward perspective (p < .001, *CI* [0.059, 0.187]).

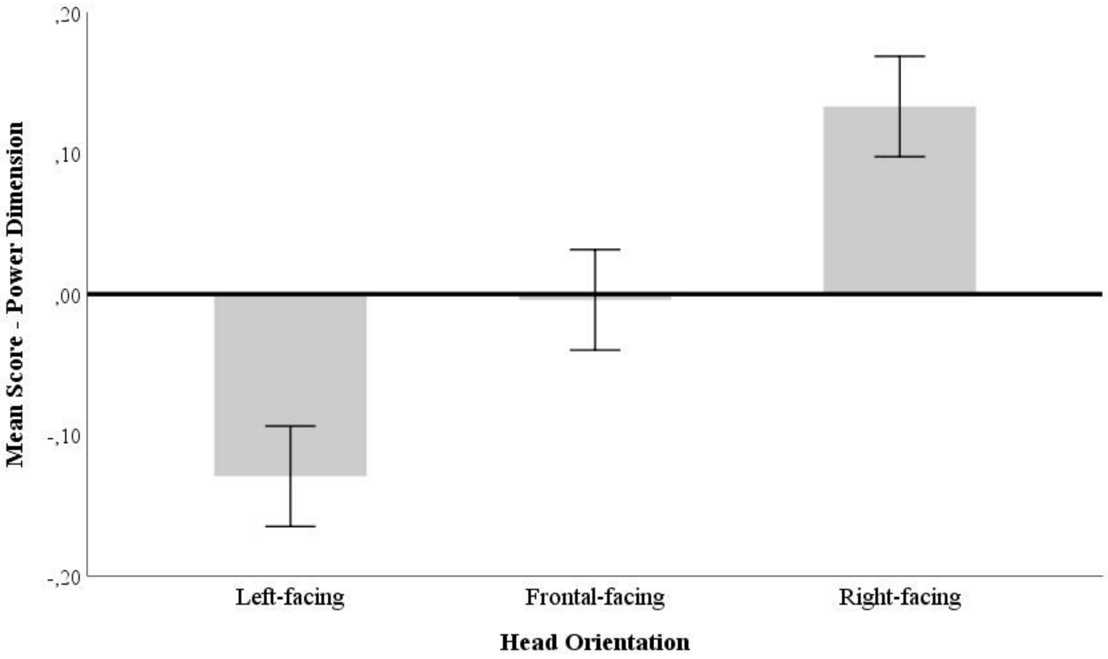

Figure 2. Mean differences for right, front, and left head orientations in the Power scale. Error bars represent the 95% confidence interval.

Although the mean differences were less pronounced for social-warmth attributions than for power judgements, social-warmth scores for right-facing faces (*M* = .088, *SE* = .018) were also significantly higher than for faces of models in frontal (*M* = -.026, *SE* = .018; *p* < .001, *CI* [0.053, 0.176]) and left-facing perspectives (*M* = -.070, *SE* = .018; *p* < .001, *CI* [0.096, 0.220]). Standardized mean differences in social-warmth related traits were not significant between front-facing and left-facing faces (*p* > .250).

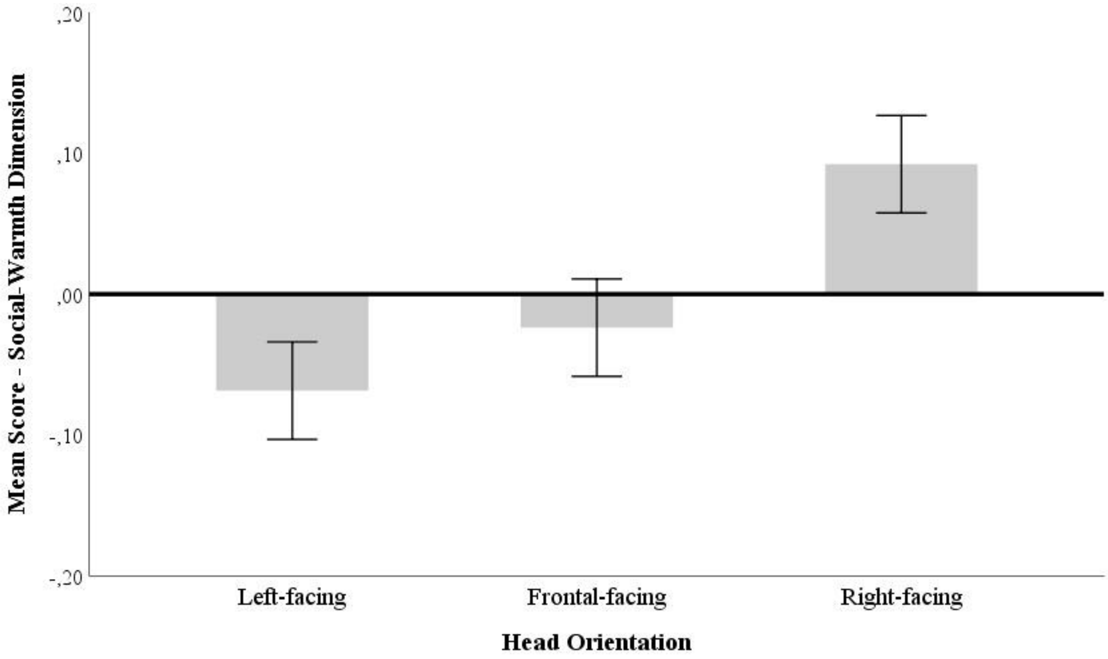

Figure 3. Mean differences for right, front, and left head orientations in the Social-Warmth scale. Error bars represent the 95% confidence interval.

As for the effect of target gender, although having yielded a multivariate effect, we did not observe significant differences in the univariate effects on power (F (1, 3858) = 2.888, p = .089, n_p^2 = .001) and social-warmth dimensions (F (1, 3858) = 1.877, p = .171, n_p^2 = .000). Finally, the interaction between head orientation and target gender yielded significant differences on the social-warmth ratings (F (2, 3858) = 3.755, p = .023, n_p^2 = .002) but not on the power ratings (F (2, 3.755) = .881, p > .250, n_p^2 = .000). When presented with front-facing faces, participants rated females with higher social-warmth (M = 0.12, SE = .026) than males (M = -0.062, SE = .025, p = .037, CI [0.05, 0.147]). These findings are not surprising given that the attribution of communal traits to females over males has been repeatedly reported in the literature (Abele, 2003).

In order to better understand how face directionality drives power-related judgements, we examined the individual contribution of the eight items previously found to have higher loadings in the power dimension as a function of the head orientation of the models in a multivariate analysis of variance. Once again head orientation yielded a significant multivariate main effect (Pillai's trace = .046, F (16, 7722) = 11.386, p < .001, n_p^2 = .023). Moreover, statistically significant univariate main effects for head position emerged across all eight items:

activity/passivity, F (2, 3867) = 10.184, p < .001, n_p^2 = .005; strength, F (2, 3867) = 15.600, p < .001, n_p^2 = .008; dominance, F(2, 3867) = 38.970, p < .001, n_p^2 = .020; competence, F (2, 3867) = 5.373, p = .005, n_p^2 = .003; agency, F (2, 3867) = 16.508, p < .001, n_p^2 = .008; speed, F (2, 3867) = 30.746, p < .001, n_p^2 = .016; temporal orientation, F (2, 3867) = 46.582, p < .001, n_p^2 = .024; and ideological orientation, F (2, 3867) = 32.492, p < .001, n_p^2 = .017.

A Bonferroni post-hoc analysis was performed to examine individual mean difference comparisons across head orientations and the eight items loading highly on the power dimension, which previously revealed a significant main effect (see Table 2**Erro! A origem da referência não foi encontrada.**).

Table 2. Mean difference comparisons between right-facing, front-facing, and left-facing perspectives in scales of activity/passivity, strength, dominance, competence, agency, speed, temporal orientation, and ideological orientation. * p < .05, ** p < .01, *** p < .001

					95% CI	
Scales	**Face Orientation**		**Mean Difference**	**SE**	**Lower Bound**	**Upper Bound**
Activity/Passivity	Right-facing	Frontal-facing	-.139*	.056	.004	.274
	(*M* = 4.02)	Left-facing	-.254***	.056	.119	.389
	Frontal-facing	Left-facing	.116	.056	-.020	.251
	(*M* = 3.88)	Right-facing	-.139*	.056	-.274	-.004
	Left-facing	Frontal-facing	.116	.056	-.251	.020
	(*M* = 3.76)	Right-facing	.254***	.056	-.389	-.119
Strength	Right-facing	Frontal-facing	.130*	.054	.001	.259
	(*M* = 4.18)	Left-facing	.300***	.054	.171	.429
	Frontal-facing	Left-facing	.170**	.054	.041	.299
	(*M* = 4.05)	Right-facing	-.130*	.054	-.259	-.001
	Left-facing	Frontal-facing	-.170**	.054	-.299	-.041
	(*M* = 3.88)	Right-facing	-.300***	.054	-.429	-.171
Dominance	Right-facing	Frontal-facing	.256***	.056	.122	.390
	(*M* = 4.09)	Left-facing	.494***	.056	.360	.628
	Frontal-facing	Left-facing	.238***	.056	.104	.372
	(*M* = 3.84)	Right-facing	-.256***	.056	-.390	-.122
	Left-facing	Frontal-facing	-.238***	.056	-.372	-.104
	(*M* = 3.60)	Right-facing	-.494***	.056	-.628	-.360
Competence	Right-facing	Frontal-facing	.070	.053	-.057	.196
	(*M* = 4.24)	Left-facing	.172**	.053	.046	.299
	Frontal-facing	Left-facing	.102	.053	-.024	.229
	(*M* = 4.71)	Right-facing	-.070	.053	-.196	.057

	Left-facing (*M* = 4.07)	Frontal-facing	-.102	.053	-.229	.024
		Right-facing	-.172**	.053	-.299	-.046
Agency	Right-facing (*M* = 4.16)	Frontal-facing	.100	.055	-.031	.231
		Left-facing	.309***	.055	.177	.440
	Frontal-facing (*M* = 4.06)	Left-facing	.209***	.055	.077	.340
		Right-facing	-.100	.055	-.231	.031
	Left-facing (*M* = 3.85)	Frontal-facing	-.209***	.055	-.340	-.077
		Right-facing	-.309***	.055	-.440	-.177
Speed	Right-facing (*M* = 4.17)	Frontal-facing	.286***	.054	.158	.415
		Left-facing	.410***	.054	.282	.539
	Frontal-facing (*M* = 3.89)	Left-facing	.124	.054	-.004	.252
		Right-facing	-.286***	.054	-.415	-.158
	Left-facing (*M* = 3.76)	Frontal-facing	-.124	.054	-.252	.004
		Right-facing	-.410***	.054	-.539	-.282
Temporal Orientation	Right-facing (*M* = 4.46)	Frontal-facing	.186**	.055	.055	.317
		Left-facing	.522***	.055	.391	.654
	Frontal-facing (*M* = 4.27)	Left-facing	.336***	.055	.205	.468
		Right-facing	-.186**	.055	-.317	-.055
	Left-facing (*M* = 3.93)	Frontal-facing	-.336***	.055	-.468	-.205
		Right-facing	-.522***	.055	-.654	-.391
Ideological Orientation	Right-facing (*M* = 4.32)	Frontal-facing	.222***	.055	-.349	-.087
		Left-facing	.440***	.055	-.571	-.309
	Frontal-facing (*M* = 4.10)	Left-facing	.218***	.055	.087	.349
		Right-facing	-.222***	.055	-.353	-.092
	Left-facing (*M* = 3.88)	Frontal-facing	-.218***	.055	.087	.349
		Right-facing	-.440***	.055	-.353	-.092

Notably, in all the above-mentioned items, mean ratings were systematically higher for right-facing photos, followed by frontal-facing and left-facing photos. Thus, mean differences between right and left-facing photos consistently presented the highest values on all item ratings, which strongly suggests a substantial impact of the rightward directionality on social perceptions, particularly on power attributions.

An additional multivariate analysis on the remaining six items with greater contribution to the second, social-warmth dimension was also conducted (for detail see SM p. 117; Table 5).

To further control for dependencies in ratings driven by the variance introduced by the target models' photos (photo ID), as well as the participants' interindividual differences (participant ID), two separate linear mixed models were conducted (LMM, one for each dimension). We started by performing a visual inspection of the residual plots that did not reveal any severe violation of the homoscedasticity or normality assumptions. Both LMM's were conducted including the photo ID and participant ID as clustering factors, the dimension (power or social-warmth) as the dependent variable, and head orientation, target gender, and participant gender as categorical independent variables.

As fixed effects in the model, we considered the head orientation, the target gender, and the participant gender as well as their second and third-order interactions. As random effects, we included random intercepts per participant and per photo. Moreover, the model was estimated using restricted maximum likelihood, and a Satterthwaite approximation of the degrees of freedom was considered (see West, 2009). The LMM analyses were performed using the GAMLj module (Gallucci, 2019) implemented with the jamovi software (The jamovi project, 2019).

Power Dimension

The LMM analysis ($R^2_{marginal} = .03$; $R^2_{conditional} = .15$), revealed a significant main effect of head orientation (F (2, 3510.2) = 56.493; $p < .001$). This main effect confirms that power ratings differed significantly across the three head orientations. Replicating what was observed in the multivariate analysis of variance, post-hoc comparisons with Bonferroni correction revealed that left-facing faces (M = -.129, SE = .017) gave rise to lower ratings of power than right-facing faces (M = .133, SE = .018; t (3510) = -10.61, $p < .001$). Frontal-facing models (M = -.004, SE = .019) also generated lower power scores than did right-facing models (t (3509) = -5.88, $p < .001$). Finally, the mean ratings' difference between left-facing and front-facing models was smaller, but nevertheless significant (t (3511) = -4.74, $p < .001$).

Notably, the LMM showed no main effect of target gender (F (1, 43.5) = 1.634, p = .208) nor of participant gender (F (1, 360.6) = .247, p = .620). In addition, we observed no interaction between head orientation and target gender (F (2, 3571.8) = .752, p = .472), no interaction between head orientation and participant gender (F (2, 3531.1) = .378, p = .686), no interaction between target gender and participant gender (F (1, 3514.4) = .847, $p < .357$), and no interaction between head orientation, target gender, and participant gender (F (2, 3577.8) = 2.070, p = .126).

Social-Warmth Dimension

The LMM analysis ($R^2_{marginal} = .02$; $R^2_{conditional} = .11$) revealed a significant main effect of head orientation (F (2, 3518.1) = 22.5364, $p < .001$), once again attesting that distinct head orientations drive social-warmth judgements differently. Post-hoc comparisons with Bonferroni correction procedure showed that left-facing models (M = -.069, SE = .017) were judged with lower social-warmth traits than right-facing models (M = .092, SE = .017; t (3518)

= -6.43, p < .001). Front-facing models (M = -.024, SE = .018) were also attributed lower social-warmth scores than right-facing models (t (3517) = -4.90, p < .001). Like what was observed in the multivariate analysis of variance, the attribution of social-warmth judgements was not different across left and frontal face perspectives (t (3519) = -1.53, p = 375).

We observed an additional interaction effect between head orientation and target gender (F (2, 3581.8) = 3.4782, p = .031). Post-hoc comparisons showed that males presented in frontal perspectives (M = -.060 SE = .025) obtained significantly lower social-warmth scores than males presented in right perspectives (M = .134, SE = .024; t (3555) = -5.227, p < .001). Left-facing males (M = -.100, SE = .021) were judged lower in social warmth than right-facing females (M = .048, SE = .026; t (191) = -4.173, p < .001). Left-facing males also obtained lower social-warmth ratings than right-facing males (t (3556) = -6.099, p < .001). Finally, right-facing males obtained higher scores than left-facing female models (M = -.035, SE = .025; t (191) = 3.898, p = .002). The remaining pairwise comparisons did not yield significantly different social-warmth ratings (all p's > .152).

The LMM revealed no main effect of participant gender (F (1, 357.4) = .2948, p = .588), no significant interaction between head orientation and participant gender (F (2, 3540.9) = .0370, p = .964), no interaction between participant gender and target gender (F (1, 3517.4) = 2.6713, p = 102), and no third-order interaction between head orientation, target gender, and participant gender (F (2, 3593.6) = 2.9113, p = .055).

In sum, after entering the photo ID and the participant ID as random coefficients, the systematic effect of rightward faces in power judgements, and to a lesser extent social-warmth judgments, remained the same. Tables 6 and 7 (for detail see SM, p. 118-119) provide an overview of the parameter estimates for the main effects and interactions with the aforementioned coefficients in the models.

Discussion

The main goal of the present study was to investigate whether distinct head orientations drive social inferences differently. Specifically, we speculated that rightward faces, because their directionality overlaps with movement representation in western scripts, would give rise to higher agency and its correlated attributes.

In the current study, we further established that face related judgments can be represented by a two-dimensional factor solution. These dimensions converge with earlier findings (Oosterhof & Todorov, 2008), which identified a valence/trustworthiness dimension and a dominance dimension. Our exploratory analysis yielded a similar two-component solution which was further confirmed by an independent sample: a dimension comprising power-related attributes (e.g., agency, dominance, strength) and a dimension comprising of traits that reflect social-warmth (e.g., familiarity, emotion, attractiveness).

The multivariate analysis of the two dimensions as a function of the three head orientations, target and participant gender yielded the expected main effect for head orientation in the power dimension but also in the social-warmth dimension. Although to a different extent, on both dimensions, we obtained higher scores for right-facing faces relative to frontal and left-facing ones. As hypothesized, this bias was substantially more pronounced on power-related judgements, which seem to be particularly susceptible to head orientation. The power-related ratings were systematically different across all three head orientations, with a clear advantage for right-facing targets, followed by frontal and finally left-facing targets. In addition, after controlling for the potential variance introduced in the ratings by the models' photos and the individual differences across participants, the results remained the same. This strengthens our account for the systematic impact rightward faces have in driving social inferences, particularly power-related ones.

In examining the univariate effects of the scales with greater weight on the power dimension, we found that aside from the expected agency-related scales (e.g., activity/passivity), the left-right asymmetry characterizes a more general dimension. Right-facing targets also induce attributes of dominance, speed, temporal and ideological orientation significantly stronger than the remaining head orientations. While the specific associations between right-facing orientation and dominance attributions has long been reported (Suitner et al., 2017), the findings on temporal and ideological attributions extend the generality of the head orientation effects.

These findings show that a wide range of social attributes are grounded on a horizontal continuum and are affected by head orientation similarly to what we termed 'power' or what was referred to in earlier research as 'agency' related attributes. Thus, the left-to-right movement encompasses a generic property that is at the core of how a wide range of categories are grounded. The significance of this work is to be seen in the fact that although these categories are not semantically related, the way they are grounded relies on a unifying principle. We propose that the overlap between agency and a substantial number of distinct but interrelated social categories is a conceptual one. The unifying principle bolstering agency-related properties elicits similar inferences by association, which are sustained by spatial representations flowing congruently with the left-to-right movement. These findings provide a more abstract and integrative framework where agency (Suitner & Maass, 2016), time (Ouellet et al., 2010) and political categories (Mills et al., 2015) are shown to be grounded on a horizontal continuum and can all be primed by head orientation.

It is important to note that the effect of the left-right movement, and by extension that of rightward faces, on social inferences is in all likelihood culture-specific, in this case circumscribed to Western script communities like our Portuguese samples (i.e., communities with rightward flowing language script). The opposite preferential representation of agency (i.e. evolving from right-to-left) has been largely reported in leftward flowing languages in distinct attentional and cognitive processes. For instance, line bisection (Chokron & Imbert, 1993), directionality in drawing side view objects (Kebbe & Vinter, 2012), time and number line representation (Dehaene et al., 1993; Ouellet et al., 2010), thematic role drawing tasks (Maass & Russo, 2003), are all heterogeneous but converging examples of how leftward speaking populations preferentially conceived movement as unfolding from right-to-left. However, most reported reversals are considerably weaker in cultures where writing is leftward (Román et al., 2013), likely due to the frequent exposure to westernized spatial layouts whereas exposure to leftward cultures in the West is less frequent. Thus, extrapolations regarding the same pattern of results driven by leftward faces in cultures with right-to-left speaking individuals (i.e., Arabic, Hebrew, Farsi) should be drawn with caution as it is difficult to assess the scope of script directionality effects without a sample from such countries.

The social-warmth dimension revealed that right-facing targets were also judged significantly higher than the left and front-facing targets, which among themselves did not differ. Although lesser in magnitude than on the power dimension, we did not anticipate the effect of head orientation on traits loading on the social-warmth dimension. In fact, previous studies reported faces with direct (relative to averted) gaze as more attractive and trustworthy because they facilitate social communication (Ewing et al., 2010; Kaisler & Leder, 2016). Nevertheless, left-to-right spatial representations seem to facilitate scanning fluency simply because they are script-coherent and hence more familiar (Chae & Hoegg, 2013). Taken together with the script-coherent direction they convey, profile rightward images are also processed with greater ease because they point to an outward direction (Leonhardt et al., 2015). Arguably, this may hint on why we also obtained an advantage, albeit more modest, for right-facing models in social-warmth judgments.

Contrary to what we had hypothesized, we did not observe a main effect of target gender neither on power ratings, particularly for male models, nor on social-warmth judgements, particularly for female models. Although the multivariate main effect of target gender was significant, the univariate effects did not reach statistical significance in either dimension. This pattern might have resulted from little statistical power to demonstrate differences on the two dimensions. Thus, future studies may require bigger samples to uncover potential differences in power and social-warmth traits as a function of the gender of the model. Notably, these results cannot be accounted for by the gender of our participants given that no interaction between these two variables was found.

Although no main effect of target gender emerged, one final consideration goes to the interaction between head orientation and target gender which is in line with our predictions. Models in frontal perspectives were assigned higher social-warmth scores when they were females, relative to males. This result reaffirms the traditional gender roles that emphasize communal-expressive traits in women, conferring them important qualities as nurturing caretakers (Abele, 2003). The effect may be prominent in this south-European sample, where the female gender role is particularly marked as compared to, for instance, countries from northern Europe. However, this interaction was rather modest (p = .023). Taken together with the absence of main effect for target gender on social inferences, it may be the case that features of our specific targets are shaping the results. Therefore, the observed gender effects should be interpreted in light of our pool of models, which is composed of young university students who may not fit the imaginary for traditional gender roles and therefore constrain possible effects.

Other authors reporting two fundamental dimensions underlying social perception (Oosterhof & Todorov, 2008) have found the first, primary component capturing face inferences to be the one conveying information on communion-related traits. In contrast, in this study, the power dimension accounted for a higher percentage of the variance in face judgements relative to the social-warmth dimension. Because our participants were not limited to frontal angles but instead produced evaluations on three face perspectives of models, we speculate that rightward oriented faces had a considerable influence on judgements. Arguably, this particular head orientation may have given rise to a substantially higher weight for the power component in overall face evaluation. This means that in a context with multiple face perspectives, power-related traits have the potential to outweigh warmth-related ones and largely contribute to the big picture of face perception.

The results obtained in this study carry important practical and theoretical implications. Research focusing on embodied processes (for reviews see Semin, Garrido, & Palma, 2013, 2012; Semin & Smith, 2013) and their evaluative consequences could benefit from the manipulation of head orientation and the related norming data made available here (see SM for detail). For instance, studies on the embodied categorization of gender frequently rely on faces to assess how abstract dimensions, such as toughness, relate to social categorization (Slepian et al., 2011). Additionally, rightward oriented face stimuli give rise to asymmetries in visual scanning which are likely to affect attentional processes and consequently person perception. Overall, averting the head laterally has been found to modify the perceived social interaction between the observer and the target (Hietanen, 2002). The acknowledgement of the SAB effect on an array of social judgements could also prove useful for practitioners in fields relying on person perception, namely politics (Farias et al., 2013, 2016; Samochowiec et al., 2010), marketing and consumer behavior (Miesler et al., 2010).

These findings constitute a preliminary yet relevant demonstration of how a particular set of social judgments, not necessarily semantically related, are tied to left-to-right distribution in written language. In addition, we build on literature showing that women and men are represented differently in the horizontal vector and capture distinct face inferences (Suitner et al., 2017). Overall, we believe this research highlights the importance of taking the target audience's script-driven asymmetry into account when representing people in space.

References

Abele, A. E. (2003). The Dynamics of Masculine-Agentic and Feminine-Communal Traits: Findings from a Prospective Study. *J. Pers. Soc. Psychol.* doi:10.1037/0022-3514.85.4.768.

Abele, A. E., and Wojciszke, B. (2014). Communal and agentic content in social cognition: A dual perspective model. *Adv. Exp. Soc. Psychol.* 50, 195–255. doi:10.1016/B978-0-12-800284-1.00004-7.

Adams, R. B. J., and Kleck, R. E. (2003). Perceived gaze direction and the processing of facial displays of emotion. *Psychol. Sci.* 14, 644–647. doi:10.1046/j.0956-7976.2003.psci_1479.x.

Allison, T., Puce, A., and McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. *Trends Cogn. Sci.* doi:10.1016/S1364-6613(00)01501-1.

Anderson, A. K., Christoff, K., Panitz, D., De Rosa, E., and Gabrieli, J. D. E. (2003). Neural correlates of the automatic processing of threat facial signals. *J. Neurosci.* 23, 5627–5633.

Bakan, D. (1995). The Duality of Human Existence: Isolation and Communion in Western Man. *Lancet*. doi:10.1016/S0140-6736(95)92959-2.

Barrett, P. (2007). Structural equation modelling: Adjudging model fit. *Pers. Individ. Dif.* 42, 815–824. doi:10.1016/j.paid.2006.09.018.

Chae, B., and Hoegg, J. (2013). The future looks “right”: Effects of the horizontal location of advertising images on product attitude. *J. Consum. Res.* 40, 223–238. doi:10.1086/669476.

Chatterjee, A. (2002). Portrait Profiles and the Notion of Agency. *Empir. Stud. Arts*. doi:10.2190/3wlf-agtv-0aw7-r2cn.

Chatterjee, A., Southwood, M. H., and Basilico, D. (1999). Verbs, events and spatial representations. *Neuropsychologia* 37, 395–402. doi:10.1016/S0028-3932(98)00108-0.

Chokron, S., and Imbert, M. (1993). Influence of reading habits on line bisection. *Brain Res. Cogn. Brain Res.* 1, 219–222. doi:10.1016/0926-6410(93)90005-p.

Csibra, G., and Gergely, G. (2009). Natural pedagogy. *Trends Cogn. Sci.* 13, 148–153. doi:10.1016/j.tics.2009.01.005.

Cuddy, A. J. C., Fiske, S. T., Kwan, V. S. Y., Glick, P., Demoulin, S., Leyens, J. P., et al. (2009). Stereotype content model across cultures: Towards universal similarities and some differences. *Br. J. Soc. Psychol.* doi:10.1348/014466608X314935.

Dehaene, S., Bossini, S., and Giraux, P. (1993). The mental representation of parity and number magnitude. *J. Exp. Psychol. Gen.* 122, 371–396. doi:10.1037/0096-3445.122.3.371.

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., and Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Vis. cogn.* 6, 509–540. doi:10.1080/135062899394920.

Emery, N. J. (2000). The eyes have it: the neuroethology, function and evolution of social gaze. *Neurosci. Biobehav. Rev.* 24, 581–604. doi:10.1016/s0149-7634(00)00025-7.

Ewing, L., Rhodes, G., and Pellicano, E. (2010). Have you got the look? gaze direction affects judgements of facial attractiveness. *Vis. cogn.* doi:10.1080/13506280902965599.

Farias, A. R., Garrido, M. V., and Semin, G. R. (2013). Converging modalities ground abstract categories: The case of politics. *PLoS One* 8, e60971. doi:10.1371/journal.pone.0060971.

Farias, A. R., Garrido, M. V., and Semin, G. R. (2016). Embodiment of abstract categories in space. . . grounding or mere compatibility effects? The case of politics. *Acta Psychol. (Amst).* 166, 49–53. doi:10.1016/j.actpsy.2016.03.002.

Fiske, S. T., Cuddy, A. J. C., and Glick, P. (2007). Universal dimensions of social cognition: warmth and competence. *Trends Cogn. Sci.* 11, 77–83. doi:10.1016/j.tics.2006.11.005.

Fiske, S. T., Cuddy, A. J. C., Glick, P., and Xu, J. (2002). A model of (often mixed) stereotype content: Competence and warmth respectively follow from perceived status and competition. *J. Pers. Soc. Psychol.* doi:10.1037/0022-3514.82.6.878.

Friesen, C. K., and Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychon. Bull. Rev.* 5, 490–495. doi:10.3758/BF03208827.

Frischen, A., Bayliss, A. P., and Tipper, S. P. (2007). Gaze cueing of attention: visual attention, social cognition, and individual differences. *Psychol. Bull.* 133, 694–724. doi:10.1037/0033-2909.133.4.694.

Gallucci, M. (2019). GAMLj: General analyses for linear models.

Garcia-Marques, T., Mackie, D. M., Claypool, H. M., and Garcia-Marques, L. (2004). Positivity Can Cue Familiarity. *Personal. Soc. Psychol. Bull.* doi:10.1177/0146167203262856.

Garrido, M. V., Lopes, D., Prada, M., Rodrigues, D., Jerónimo, R., and Mourão, R. P. (2017).

The many faces of a face: Comparing stills and videos of facial expressions in eight dimensions (SAVE database). *Behav. Res. Methods*. doi:10.3758/s13428-016-0790-5.

Hair, J. F., Black, W. C., Babin, B. J., and Anderson, R. E. (2014). *Multivariate Data Analysis*. doi:10.1016/j.ijpharm.2011.02.019.

Hietanen, J. K. (1999). Does your gaze direction and head orientation shift my visual attention? *NeuroReport Rapid Commun. Neurosci. Res.* 10, 3443–3447. doi:10.1097/00001756-199911080-00033.

Hietanen, J. K. (2002). Social attention orienting integrates visual information from head and body orientation. *Psychol. Res.* 66, 174–9. doi:10.1007/s00426-002-0091-8.

Hietanen, J. K., Leppänen, J. M., Peltola, M. J., Linna-aho, K., and Ruuhiala, H. J. (2008). Seeing direct and averted gaze activates the approach-avoidance motivational brain systems. *Neuropsychologia* 46, 2423–2430. doi:10.1016/j.neuropsychologia.2008.02.029.

Hitlin, S., and Elder, G. H. (2007). Time, self, and the curiously abstract concept of agency*. *Sociol. Theory*. doi:10.1111/j.1467-9558.2007.00303.x.

Hoffman, E. A., and Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nat. Neurosci.* doi:10.1038/71152.

Hooker, C. I., Paller, K. A., Gitelman, D. R., Parrish, T. B., Mesulam, M. M., and Reber, P. J. (2003). Brain networks for analyzing eye gaze. *Cogn. Brain Res.* doi:10.1016/S0926-6410(03)00143-5.

Hu, L. T., and Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Struct. Equ. Model.* 6, 1–55. doi:10.1080/10705519909540118.

Kaisler, R. E., and Leder, H. (2016). Trusting the Looks of Others: Gaze Effects of Faces in Social Settings. *Perception*. doi:10.1177/0301006616643678.

Kebbe, H., and Vinter, A. (2012). How culture, age, and manual dominance affect directionality in drawing side view objects. *J. Cross. Cult. Psychol.* 44, 160–172. doi:10.1177/0022022111435098.

Kobayashi, H., and Kohshima, S. (2001). Unique morphology of the human eye and its adaptive meaning: comparative studies on external morphology of the primate eye. *J. Hum. Evol.*

40, 419–435. doi:10.1006/jhev.2001.0468.

Lakens, D., Semin, G. R., and Garrido, M. V. (2011). The sound of time: Cross-modal convergence in the spatial structuring of time. *Conscious. Cogn.* 20, 437–43. doi:10.1016/j.concog.2010.09.020.

Langner, O., Dotsch, R., Bijlstra, G., Wigboldus, D. H. J., Hawk, S. T., and van Knippenberg, A. (2010). Presentation and validation of the radboud faces database. *Cogn. Emot.* doi:10.1080/02699930903485076.

Leonhardt, J. M., Catlin, J. R., and Pirouz, D. M. (2015). Is your product facing the Ad's center? Facing direction affects processing fluency and ad evaluation. *J. Advert.* 44, 315–325. doi:10.1080/00913367.2015.1048911.

Ma, D. S., Correll, J., and Wittenbrink, B. (2015). The Chicago face database: A free stimulus set of faces and norming data. *Behav. Res. Methods*. doi:10.3758/s13428-014-0532-5.

Maass, A., Pagani, D., and Berta, E. (2007). How beautiful is the goal and how violent is the fistfight? Spatial bias in the interpretation of human behavior. *Soc. Cogn.* 25, 833–852. doi:10.1521/soco.2007.25.6.833.

Maass, A., and Russo, A. (2003). Directional bias in the mental representation of spatial events: Nature or culture? *Psychol. Sci.* 14, 296–301. doi:10.1111/1467-9280.14421.

Maass, A., Suitner, C., Favaretto, X., and Cignacchi, M. (2009). Groups in space: Stereotypes and the spatial agency bias. *J. Exp. Soc. Psychol.* 45, 496–504. doi:10.1016/j.jesp.2009.01.004.

Maass, A., Suitner, C., and Nadhmi, F. (2014). What drives the spatial agency bias? An Italian-Malagasy-Arabic comparison study. *J. Exp. Psychol. Gen.* 143, 991–996. doi:10.1037/a0034989.

Marôco, J. (2014). *Análise de Equações Estruturais: Fundamentos teóricos, software & aplicações*. Pêro Pinheiro: ReportNumber.

Miesler, L., Landwehr, J. R., Herrmann, A., and McGill, A. (2010). Consumer and Product Face-To-Face: Antecedents and Consequences of Spontaneous Face-Schema Activation. *ACR North Am. Adv.* NA-37.

Mills, M., Smith, K. B., Hibbing, J. R., and Dodd, M. D. (2015). Obama cares about visuo-spatial attention: Perception of political figures moves attention and determines gaze direction. *Behav. Brain Res.* 278, 221–225. doi:10.1016/j.bbr.2014.09.048.

O'Reilly, H., Pigat, D., Fridenson, S., Berggren, S., Tal, S., Golan, O., et al. (2016). The EU-Emotion Stimulus Set: A validation study. *Behav. Res. Methods*. doi:10.3758/s13428-015-0601-4.

Oosterhof, N. N., and Todorov, A. (2008). The functional basis of face evaluation. *Proc. Natl. Acad. Sci. U. S. A.* doi:10.1073/pnas.0805664105.

Ouellet, M., Santiago, J., Israeli, Z., and Gabay, S. (2010). Is the future the right time? *Exp. Psychol.* 57, 308–314. doi:10.1027/1618-3169/a000036.

Palanica, A., and Itier, R. J. (2012). Attention Capture by Direct Gaze is Robust to Context and Task Demands. *J. Nonverbal Behav.* doi:10.1007/s10919-011-0128-z.

Penton-Voak, I. S., Pound, N., Little, A. C., and Perrett, D. I. (2006). Personality judgments from natural and composite facial images: More evidence for a "kernel of truth" in social perception. *Soc. Cogn.* 24, 607–640. doi:10.1521/soco.2006.24.5.607.

Prentice, D. A., and Carranza, E. (2002). What women and men should be, shouldn't be, are allowed to be, and don't have to be: The contents of prescriptive gender stereotypes. *Psychol. Women Q.* doi:10.1111/1471-6402.t01-1-00066.

Raykov, T. (2001). Bias of coefficient α for fixed congeneric measures with correlated errors. *Appl. Psychol. Meas.* 25, 69–76. doi:10.1177/01466216010251005.

Reise, S. P. (2012). The Rediscovery of Bifactor Measurement Models. *Multivariate Behav. Res.* 47, 667–696. doi:10.1080/00273171.2012.715555.

Román, A., El Fathi, A., and Santiago, J. (2013). Spatial biases in understanding descriptions of static scenes: The role of reading and writing direction. *Mem. Cogn.* 41, 588–599. doi:10.3758/s13421-012-0285-2.

Samochowiec, J., Wänke, M., and Fiedler, K. (2010). Political Ideology at Face Value. *Soc. Psychol. Personal. Sci.* doi:10.1177/1948550610372145.

Santiago, J., Lupiáñez, J., Pérez, E., and Funes, M. J. (2007). Time (also) flies from left to right. *Psychon. Bull. Rev.* 14, 512–516. doi:10.3758/BF03194099.

Sato, W., and Yoshikawa, S. (2013). Recognition memory for faces and scenes. *J. Gen. Psychol.* doi:10.1080/00221309.2012.710275.

Semin, G. R., Garrido, M. V., and Palma, T. (2013). Interfacing Body, Mind, the Physical, and the Social World: Socially Situated Cognition. *Oxford Handb. Soc. Cogn.* doi:10.1093/oxfordhb/9780199730018.013.0031.

Semin, G. R., Garrido, M. V., and Palma, T. A. (2012). "Socially situated cognition: Recasting social cognition as an emergent phenomenon," in *The SAGE Handbook of Social Cognition* doi:10.4135/9781446247631.n8.

Semin, G. R., and Smith, E. R. (2013). Socially situated cognition in perspective. *Soc. Cogn.* doi:10.1521/soco.2013.31.2.125.

Simpson, E. A., Buchin, Z., Werner, K., Worrell, R., and Jakobsen, K. V (2014). Finding faces among faces: human faces are located more quickly and accurately than other primate and mammal faces. *Atten. Percept. Psychophys.* 76, 2175–2183. doi:10.3758/s13414-014-0744-x.

Slepian, M. L., Weisbuch, M., Rule, N. O., and Ambady, N. (2011). Tough and tender: Embodied categorization of gender. *Psychol. Sci.* doi:10.1177/0956797610390388.

Stroustrup, S., and Wallentin, M. (2018). Grammatical category influences lateralized imagery for sentences. *Lang. Cogn.* 10, 193–207. doi:10.1017/langcog.2017.19.

Suitner, C., and Maass, A. (2016). Spatial agency bias: Representing people in space. *Adv. Exp. Soc. Psychol.* 53, 245–301. doi:10.1016/bs.aesp.2015.09.004.

Suitner, C., Maass, A., and Ronconi, L. (2017). From spatial to social asymmetry: Spontaneous and conditioned associations of gender and space. *Psychol. Women Q.* 41, 46–64. doi:10.1177/0361684316676045.

The jamovi project (2019). jamovi.

Vandenberg, R. J. (2006). Statistical and methodological myths and urban legends: Where, pray tell, did they get this idea? *Organ. Res. Methods* 9, 194–201. doi:10.1177/1094428105285506.

Walker, M., and Vetter, T. (2009). Portraits made to measure: Manipulating social judgments about individuals with a statistical face model. *J. Vis.* doi:10.1167/9.11.1.

Wallentin, M., Rocca, R., and Stroustrup, S. (2019). Grammar, Gender and Demonstratives in Lateralized Imagery for Sentences. *J. Psycholinguist. Res.* 48, 843–858. doi:10.1007/s10936-019-09634-1.

West, B. T. (2009). Analyzing longitudinal data with the linear mixed models procedure in

SPSS. *Eval. Heal. Prof.* 32, 207–228. doi:10.1177/0163278709338554.

Wiggins, J. S. (1979). A psychological taxonomy of trait-descriptive terms: The interpersonal domain. *J. Pers. Soc. Psychol.* doi:10.1037/0022-3514.37.3.395.

Willis, J., and Todorov, A. (2006). First impressions: Making up your mind after a 100-ms exposure to a face. *Psychol. Sci.* doi:10.1111/j.1467-9280.2006.01750.x.

Wojciszke, B. (1994). Multiple Meanings of Behavior: Construing Actions in Terms of Competence or Morality. *J. Pers. Soc. Psychol.* doi:10.1037/0022-3514.67.2.222.

Supplementary Material

Development of the Stimuli Set

Models were university students from the host institution and accepted to participate as volunteers. Photo sessions were conducted individually at the psychology laboratory of the host institution. Upon arrival participants signed an informed consent granting permission for the use of the resulting photos for scientific dissemination purposes. The informed consent clearly stated that the model volunteers would take photos in different perspectives to incorporate a photo database which would be made available for research purposes. To minimize the possibility of interference of extra-facial cues on face judgement, we asked all participants to wear black t-shirts and remove most accessories, glasses, and intense makeup. Nevertheless, we opted to include faces with minor pieces of jewelry, such as earrings, light make-up, and photos of male models with facial hair as we believe these features enhance the ecological validity of the face set.

We used a Canon reflex digital camera (Model EOS 400D) with a resolution of 10.1Mpx and a 40-mm Canon EF-S lens mount. An armchair was positioned against a uniform grey wall and the camera was placed on a tripod fixed at a distance of approximate 90 cm from the chair. The experimenter instructed participants to sit in an upright position and pose with a neutral expression. Photographs were taken from three different perspectives corresponding to three different head positions: frontal, facing left and facing right. Gaze direction was contingent to the head orientation of the models. To ensure minimal display of emotion, several shots were taken per model and per head position so models could practice a neutral expression. For each model and head direction, the photo with overall better quality, position and expression was selected by three independent judges to be included in the final stimuli set. All models in the three head positions resulted in a total of 129 photos (43 for each orientation).

The original dimensions of the photos were 3888 (wide) x 2592 pixels (high). All photographs were then converted from raw to JPEG format, controlled for shadowing, equated for color temperature and the background was corrected for white-balance using Adobe Photoshop CS5 software. An alignment grid was fit over all photos and adjusted accordingly to ensure face position standardization. The resulting photos were cropped and resized into a rectangular frame of 2006 x 2006 pixels to include models' shoulders and head.

Exploratory Factor Analysis

As a preliminary first step, the 14 scales were submitted to an exploratory factor analysis. A direct oblimin rotation was employed allowing the factors to remain oblique given that social traits are likely to be correlated. To inspect the reliability of participants' responses, we conducted a first analysis by having the entire dataset split in two halves. In both analyses, a similar two-factor solution emerged (Table 3), with the first analysis explaining a total of 53.37% of the variance in the first sample and the second analysis explaining a total of 52.97% of the variance in the second sample. Having established the reliability of participants' answers across the sample, we proceeded with the analysis for the entire dataset from which two factors were extracted and correspondingly labeled (Table 4).

Table 3. Exploratory factor analysis by random split half with factor loadings for each factor with item loadings above .30.

Scales	**Factor**	
	1	**2**
Attractiveness		.505
Familiarity		.562
Emotion		.679
Valence		.596
Activity/Passivity	.764	
Strength	.847	
Dominance	.867	
Trustworthiness		.714
Warmth		.894
Competence	.432	.313
Agency	.643	
Speed	.734	
Temporal Orientation	.538	
Ideological Orientation	.423	
Eigenvalue	6.218	1.254
Explained Variance	44.415%	8.958%
Overall Accumulated Variance	53.373%	
KMO and Bartlett's Sphericity Test	KMO = .931; Chi-Square: 5244.157, $p < .001$	

Scales	**Factor**	
	1	**2**
Attractiveness		.564
Familiarity		.691
Emotion		.628
Valence		.523
Activity/Passivity	.757	
Strength	.793	
Dominance	.842	
Trustworthiness		.679
Warmth		.870
Competence	.387	.362
Agency	.688	
Speed	.738	
Temporal Orientation	.642	
Ideological Orientation	.651	
Eigenvalue	6.215	1.201
Explained Variance	44.392%	8.578%
Overall Accumulated Variance	52.970%	
KMO and Bartlett's Sphericity Test	KMO = .930; Chi-Square: 5480.307, $p < .001$	

Table 4. Exploratory factor analysis to the entire dataset with factor loadings for each factor with item loadings above .30.

Scales	**Factor 1 (Power)**	**Factor 2 (Social-Warmth)**
Attractiveness		.529
Familiarity		.624
Emotion		.650
Valence		.562
Activity/Passivity	.766	
Strength	.826	
Dominance	.864	
Trustworthiness		.708
Warmth		.880
Competence	.407	.338
Agency	.666	
Speed	.746	
Temporal Orientation	.592	
Ideological Orientation	.541	
Eigenvalue	6.213	1.218
Explained Variance	44.380%	8.702%
Overall Accumulated Variance	53.082%	
KMO and Bartlett's Sphericity Test	KMO = .935; Chi-Square: 10627.159, $p < .001$	

Confirmatory Factor Analysis

We submitted the suggested two-factor solution obtained in the EFA to a confirmatory factor analysis with an independent sample. The model was specified with the two latent factors labeled ‘power’ and ‘social-warmth’. The power factor was comprised of the following items: Activity/passivity, strength, dominance, competence, agency, speed, temporal orientation, and ideological orientation. The social-warmth score encompassed the following items: Attractiveness, familiarity, emotion, valence, trustworthiness, and warmth (Model 1, see Figure 4). Furthermore, because the competence trait was found to have a similar contribution to both factors, we tested an alternative model with the item competence on the factor ‘social-warmth’ (Model 2, see Figure 5).

Due to the assessment method (i.e., questionnaire) having similarly worded items, that is, certain items sharing similar content because they are driven from analogous literature, we correlated residuals for items of trustworthiness and warmth, dominance and strength, dominance and activity/passivity, and temporal orientation and ideological orientation (Brown, 2015).

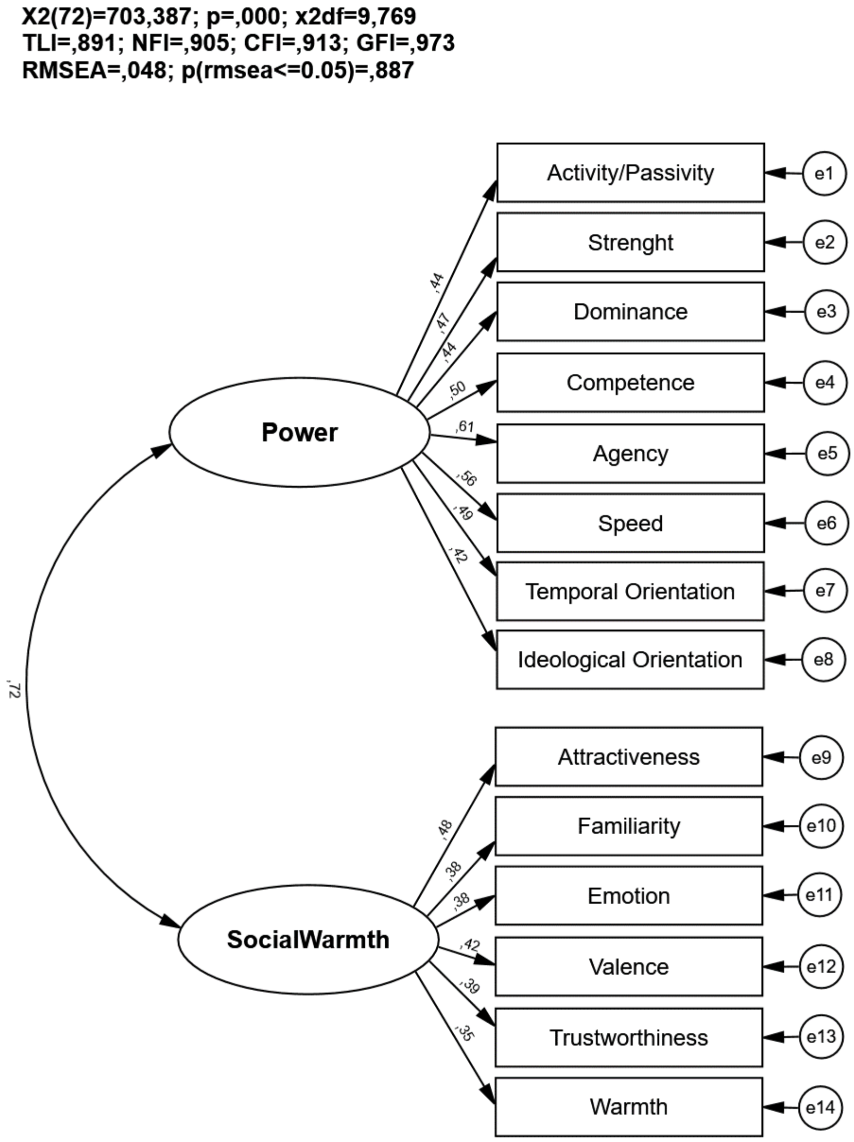

Figure 4. Confirmatory factor analysis (Model 1 – Competence on factor ‘power’).

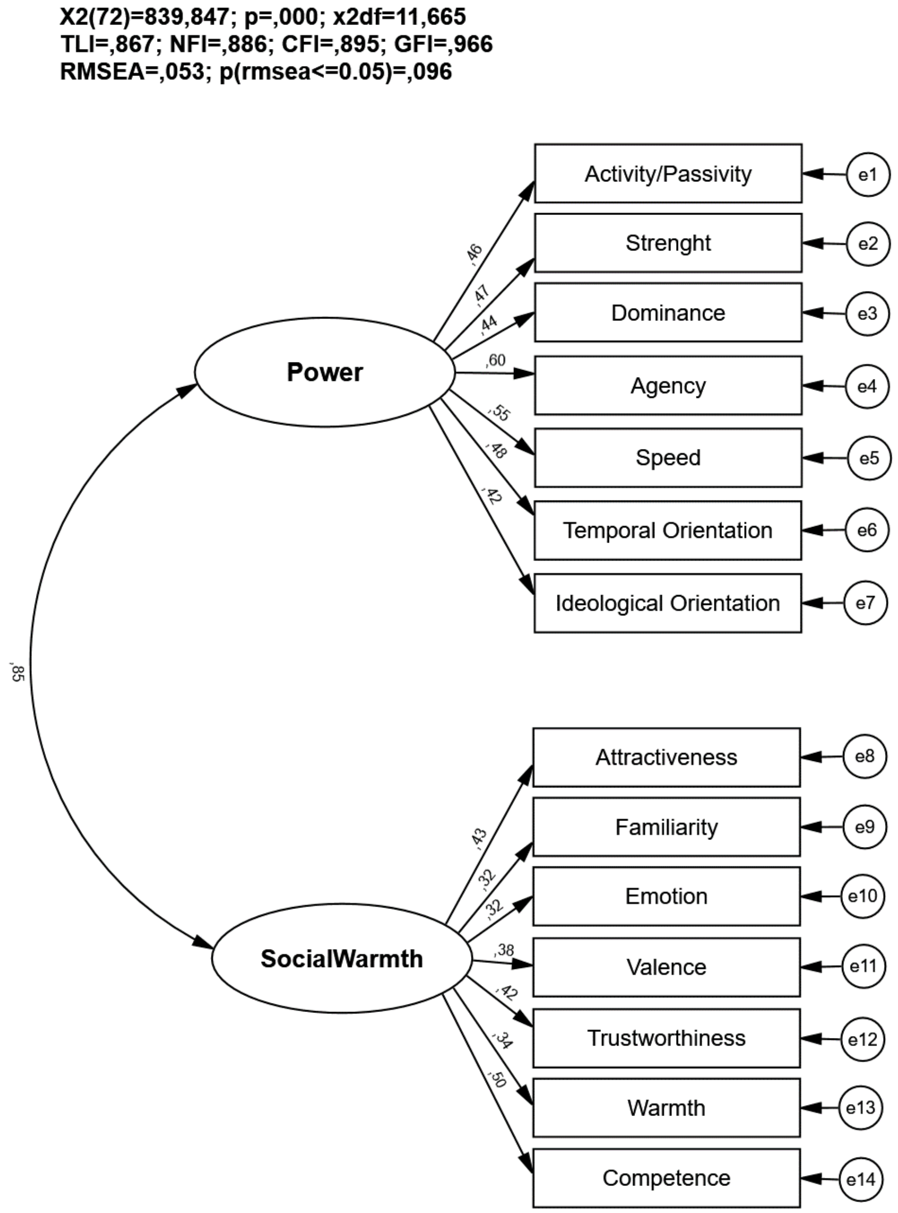

Figure 5. Confirmatory factor analysis (Model 2 – Competence on factor 'social-warmth').

Subjective Rating Norms

As a supplementary analysis we conducted a multivariate analysis of variance to examine the items of attractiveness, familiarity, emotion, valence, trustworthiness, and warmth as a function of the head orientation of the models. The social-warmth dimension, highly driven by the items mentioned above, had been found to be affected by head orientation although to a lesser extent than the power dimension. As expected, head orientation produced a significant multivariate main effect (Pillai's trace = 0.12, F (12, 7726) = 4.041, p < .001, n_p^2 = .006). An examination of the univariate main effects revealed that five of the six items were significant, namely attractiveness (F (2, 3867) = 3.370, p = .034, n_p^2 = .002, familiarity (F (2, 3867) =7.229, p = .001, n_p^2 = .004), emotion (F (2, 3867) = 6.632, p = .001, n_p^2 = .003, valence (F(2, 3867) = 3.711, p = .025, n_p^2 = .002, and warmth (F (2, 3867) = 8.283, p < .001, n_p^2 = .004). A Bonferroni post-hoc analysis was performed to examine individual mean difference comparisons across the three head orientations and the five items which revealed significant differences (Table 5). Ratings in items of attractiveness, familiarity, and emotion were systematically higher for right-facing faces relative to left-facing faces. Right-facing faces produced higher ratings than front-facing faces in items of valence and warmth.

Table 5. Mean difference comparisons between right-facing, frontal-facing, and left-facing perspectives in scales of attractiveness, familiarity, emotion, valence, and warmth. * *p* < .05, ** *p* < .01, *** *p* < .001

Scales	Face Orientation		Mean Difference	SE	95% CI Lower Bound	95% CI Upper Bound
Attractiveness	Right-facing (*M* = 3.69)	Frontal-facing	.102	.059	-.038	.243
		Left-facing	.149*	.059	.008	.289
	Frontal-facing (*M* = 3.59)	Left-facing	.047	.059	-.094	.187
		Right-facing	-.102	.059	-.243	.038
	Left-facing (*M* = 3.54)	Frontal-facing	-.047	.059	-.187	.094
		Right-facing	-.149*	.059	-.289	-.008
Familiarity	Right-facing (*M* = 3.79)	Frontal-facing	.222	.062	.072	.371
		Left-facing	.184**	.062	.034	.333
	Frontal-facing (*M* = 3.56)	Left-facing	-.038	.062	-.187	.111
		Right-facing	-.222***	.062	-.371	-.072
	Left-facing (*M* = 3.59)	Frontal-facing	.038	.062	-.111	.187
		Right-facing	-.184**	.062	-.333	-.034
Emotion	Right-facing (*M* = 3.69)	Frontal-facing	-.010	.061	-.157	.136
		Left-facing	.188**	.061	.041	.334
	Frontal-facing (*M* = 3.70)	Left-facing	.198**	.061	.051	.344
		Right-facing	.010	.061	-.136	.157
	Left-facing (*M* = 3.50)	Frontal-facing	-.198**	.061	-.344	-.051
		Right-facing	-.188**	.061	-.334	-.041
Valence	Right-facing (*M* = 4.00)	Frontal-facing	.136*	.052	.011	.260
		Left-facing	.104	.052	-.021	.229
	Frontal-facing (*M* = 3.86)	Left-facing	-.032	.052	-.157	.093
		Right-facing	-.136*	.052	-.260	-.011
	Left-facing (*M* = 3.90)	Frontal-facing	.032	.052	-.093	.157
		Right-facing	-.104	.052	-.229	.021
Warmth	Right-facing (*M* = 3.90)	Frontal-facing	.216***	.053	.088	.343
		Left-facing	.092	.053	-.035	.219
	Frontal-facing (*M* = 3.68)	Left-facing	-.123	.053	-.251	.004
		Right-facing	-.216***	.053	-.343	-.088
	Left-facing (*M* = 3.81)	Frontal-facing	.123	.053	-.004	.251
		Right-facing	-.092	.053	-.219	.035

As a further analysis, and in order to control for the potential influence of the variance introduced by the photo ID and the participants ID in the subjective ratings, two linear mixed models were conducted (LMM, one for each dimension). Photo ID and participant ID were entered as clustering variables, power and social-warmth dimension as the dependent variables in their corresponding models, and head orientation, target gender, and participant gender as categorical independent variables. Fixed effects were set for variables of head orientation, target gender, and participant gender as well as their 2-way and 3-way interactions. As random effects, we included random intercepts per participant and per photo. Tables 6 and 7 below provide an overview of the estimates for the main effects and interactions with the aforementioned parameters in the models.

Table 6. Principal main effects and interactions, with photo ID and participant ID as random coefficients in the LMM for the power dimension. *** $p < .001$

			95% CI		
	Effect	**B**	**Lower**	**Upper**	***t***
Head Orientation1	Frontal – Left	.119	.0697	.1679	4.7432***
Head Orientation2	Right – Left	.266	.2170	.3153	10.6098***
Target Gender1	Female – Male	-.039	-.0991	.0209	-1.2784
Participant Gender1	Female – Male	-.016	-.0771	.0459	-.4965
Head Orientation1 * Target Gender1	Frontal – Left * Female-Male	.012	-.0868	.1105	.2359
Head Orientation2 * Target Gender1	Right – Left * Female - Male	-.047	-.1455	.0522	-.9250
Head Orientation1 * Participant Gender1	Frontal – Left * Female - Male	-.007	-.1053	.0917	-.1354
Head Orientation2 * Participant Gender1	Right – Left * Female - Male	.034	-.0646	.1326	.6756
Target Gender1 * Participant Gender 1	Female – Male * Female - Male	.038	-.0426	.1182	.9206
Head Orientation1 * Target Gender1*Participant Gender1	Frontal – Left * Female – Male * Female - Male	-.009	-.2064	.1891	-.0860
Head Orientation2 * Target Gender1*Participant Gender1	Right – Left * Female – Male * Female – Male	.174	-.0244	.3720	1.7182

Table 7. Principal main effects and interactions, with photo ID and participant ID as random coefficients in the LMM for the social-warmth dimension. * $p < .05$, *** $p < .001$

			95% CI		
	Effect	**B**	**Lower**	**Upper**	***t***
Head Orientation1	Frontal – Left	.038	-.0105	-.08595	1.535
Head Orientation2	Right – Left	.158	.1101	.20665	6.428***
Target Gender1	Female – Male	.027	-.0256	.08022	1.013
Participant Gender1	Female – Male	-.016	-.0722	.04090	-.543
Head Orientation1 * Target Gender1	Frontal – Left * Female-Male	.012	-.0844	.10924	.252
Head Orientation2 * Target Gender1	Right – Left * Female - Male	-.106	-.2034	-.00937	-2.149*
Head Orientation1 * Participant Gender1	Frontal – Left * Female - Male	-.007	-.1039	.08937	-.147
Head Orientation2 * Participant Gender1	Right – Left * Female - Male	.006	-.0907	.10295	.124
Target Gender1 * Participant Gender 1	Female – Male * Female - Male	.066	-.0131	.14473	1.634
Head Orientation1 * Target Gender1 * Participant Gender1	Frontal – Left * Female – Male * Female - Male	.023	-.1712	.21683	.231
Head Orientation2 * Target Gender1 * Participant Gender1	Right – Left * Female – Male * Female – Male	.218	.0234	.41237	2.196*

References

Brown, T. (2015). *Confirmatory Factor Analysis for Applied Research, Second Edition*. The Guilford Press.

Chapter III.
Asymmetric practices of reading and writing shape visuospatial attention and discrimination

Chapter based on:

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Abstract

Movement is generally conceived of as unfolding laterally in the writing direction that one is socialized into. In ‘Western’ languages, this is a left-to-right bias contributing to an imbalance in how attention is distributed across space. We propose that the rightward attentional bias exercises an additional unidirectional influence on discrimination performance thus shaping the congruency effect typically observed in Posner-inspired cueing tasks. In two studies, we test whether faces averted laterally serve as attention orienting cues and generate differences in both target discrimination latencies and gaze movements across left and right hemifields. Results systematically show that right-facing faces (i.e. aligned with the script direction) give rise to an advantage for cue-target pairs pertaining to the right (versus left) side of space. We report an asymmetry between congruent conditions in the form of right-sided facilitation for: a) response time in discrimination decisions (experiment 1-2) and b) eye-gaze movements, namely earlier onset to first fixation in the respective region of interest (experiment 2). Left and front facing cues generated virtually equal exploration patterns, confirming that the latter did not prime any directionality. These findings demonstrate that visuospatial attention and consequent discrimination are highly dependent on the asymmetric practices of reading and writing.

Keywords

Visual attention; Spatial bias; Spatial asymmetries; Face cueing; Eye-tracking.

Introduction

Visual scanning of space is not a random process but reveals different systematic biases (Benwell et al., 2013; Chen & Spence, 2017). One such bias is driven by cultural habits that are associated with reading and writing practices (Suitner & Maass, 2016). This bias in movement of visual scanning unfolds laterally in the direction of the writing and reading practices of the language one is socialized in. In the case of Western cultures, this is a left-to-right bias. Such culturally established habits modulate the spatial order and consequently underlie the representation of space (Jahn et al., 2007; Maass et al., 2007). The objective of the current studies is to examine whether the rightward attentional bias driven by the culturally anchored direction of movement influences the congruency effect typically observed in Posner-inspired cueing tasks. The congruency effect shows that when cue indication and target location are consistent, performance (e.g., target discrimination latency) is enhanced. It is hindered when cue indication and target location are inconsistent (Posner, 1980). The central and novel feature of the two experiments reported here, is twofold: the conjunction of head orientation and gaze as directional spatial cues, namely faces averted laterally (to the right or the left), and a highly demanding discrimination task which prompts automatic responses within a brief response interval. We expected an asymmetry for congruent face cue-target combinations. The prediction was that faces laterally averted rightward as cues (i.e. congruent with script direction) would be consistent with the overlearned left-to-right trajectory and therefore advantage target discrimination and eye-gaze movements to targets located at the right compared to the condition with leftward averted faces as cues.

In the following, we present first the background to the current research, namely the ‘spatial agency bias’ (SAB, for a review see (Suitner & Maass, 2016)) along with the research it has generated on attentional and cognitive processing. Subsequently, we briefly present the rationale of the methodological approach we used for the spatial cueing tasks. Finally, an overview of the two experiments is provided.

Spatial Agency Bias

There is to date considerable evidence that the mental models we use to navigate the social world, anticipate actions, make predictions, reason and solve problems are biased by the cultural convention of text direction (Román et al., 2015). This assumption is largely anchored in the spatial agency bias model. Because in ‘Western’ languages script direction, and therefore motion, unfolds rightward people favor representations in which the agent is spatially positioned to the left of the recipient of the action (Chatterjee et al., 1999). There is also a preferential directionality when representing social groups in space, with stereotypically agentic groups (e.g., males, young people) being systematically placed to the left of groups with less agentic qualities (e.g., females, old people) (Abele & Wojciszke, 2014). The opposite holds for languages such as Arabic and Hebrew where the use of spatial information is reversed, that is, action progresses from right to left. However, this effect is considerably weaker in cultures where writing is leftward (Román et al., 2013), likely due to the existing exposure to westernized spatial layouts whereas exposure to leftward cultures in the West is virtually nonexistent.

These habitualized asymmetric practices permeate a wide range of attentional and cognitive processes well beyond the activities of reading and writing. For instance, script direction affects the mental representation of time (Blom & Semin, 2013; Fuhrman & Boroditsky, 2010; Ouellet, Santiago, Israeli, et al., 2010), political landscape (Farias et al., 2013; Mills et al., 2014), numerical magnitude (SNARC effect (Shaki et al., 2009)), or ordinal and action sequences both in adults (Gevers et al., 2003; Shaki & Gevers, 2011) and preverbal infants (Bulf et al., 2017). Importantly, these overlapping regularities derived from the left-to-right movement continuum do not stem from language and symbolic knowledge acquisition alone but instead are assimilated throughout continuous exposure to everyday activities (e.g., bookshelf organization (Maass, Suitner, & Deconchy, 2014); visual representation on Websites (Hernandez et al., 2017)).

A commonly reported phenomenon in attention-demanding visual tasks is the unequal distribution of visuospatial attention towards the left side of space (i.e. pseudoneglect (Jewell & McCourt, 2000)) resulting, for instance, in the misbisection of a horizontal line with significant leftward deviation of veridical midpoint (Sosa et al., 2010). While the left hemispace bias is likely the product of right hemispheric specialization for visuospatial attention (McCourt & Jewell, 1999), virtually all studies investigating left biases in spatial attention report a subgroup of rightward biased individuals (Jewell & McCourt, 2000). What is interesting is that the preference for the left hemispace can be modulated in the opposite direction when tasks are performed by readers from right-to-left speaking countries (Afsari et al., 2016; Smith & Elias, 2013). This indicates that cultural factors such as native reading direction may, at the very least, attenuate to a certain extent the predisposition to overattend to the left side of space. Thus, culturally and biologically-determined accounts of the laterality of the visual attention system are not mutually exclusive but complementary instead, as this imbalance in visual attention is likely a combination of a person’s primary writing system and hemispheric specialization (Bulf et al., 2017; Rinaldi et al., 2014; Smith et al., 2020).

Indeed, a solid corpus of research has shown that reading and writing scanning habits produce a critical left-anchoring tendency in scanning strategies (Afsari et al., 2018; Rayner, 1998; von Hecker et al., 2016). In an early report, using gaze-contingent moving windows, Pollatsek and colleagues (Pollatsek et al., 1981) found that participants deployed visual attention to the right while a mirror reversal was found for participants reading in Hebraic. Furthermore, task performance is enhanced when target stimuli flow in a script-coherent direction because one is able to anticipate the occurrence of future information and predict where a moving target will end up (Spalek & Hammad, 2004, 2005). Likewise, in a serial visual search task, left-to-right readers exhibited more accurate detections for the right hemifield and right-to-left readers for the left hemifield (Kermani et al., 2018). Notably, there was negligible lateralization for bidirectional readers of English and Farsi. In the same vein, in a series of eye-tracking experiments, Afsari and colleagues (Afsari et al., 2016) reported bilinguals from languages with opposing scripts to display flexibility in changing the direction of the spatial bias according to the type of text they read prior to freely exploring images. Hence, if attentional biases can be mitigated through exposure to distinct scanning habits, a culturally based account must be at the core of preferences in spatial exploration.

Overview of the Methodology

Visuospatial attention has been examined with variations of Posner-inspired cueing tasks (Driver et al., 1999; Langton & Bruce, 1999; Posner, 1980). It is well-established that when cue indication and target location are consistent, performance is enhanced, and hindered when cue indication and target location are inconsistent (Posner & Cohen, 1984). While this pattern holds for most studies, cue stimuli combining both head orientation and gaze direction can be powerful in Posner-inspired cueing tasks because it is well known that humans are positively tuned to lock onto others' gaze. Indeed, both gaze direction and face orientation have long been used as directional prime cues to investigate visual performance (for a review see (Frischen et al., 2007)). Human faces have been shown to be remarkably reliable triggers of attention shifts (Hietanen, 2002; Sajjacholapunt & Ball, 2014). For example, Driver and colleagues (Driver et al., 1999) found centrally presented face and gaze cues to evoke faster discrimination of peripheral target letters on the side the face gazed towards, even though participants were told the targets were four times more likely to appear on the opposite side. However, studies relying on faces cues have inspected gaze as a precursor of social interaction, focusing on the effects of, for instance, direct versus averted gaze (Yokoyama et al., 2014), or the combined effect of gaze direction and facial expression on cueing spatial attention (Pecchinenda et al., 2008). The joint influence of combined gaze and head orientation and their implied directional flow on target discrimination is still scarce.

Because faces are distinctive due to their biological relevance, they trigger attentional shifts and facilitate processing at congruent locations even without awareness (Axelrod et al., 2015; Sato et al., 2007). Eyes and attention continuously shift together in space and are indeed biased by the direction signaled by gaze (Zwickel & Melissa, 2010). For instance, Mansfield and colleagues (Mansfield et al., 2003) reported spontaneous saccades following an averted gaze cue but prior to target onset which reinforces their automatic nature. Similarly, face cues but not arrows produce less accurate saccades to a target in incongruent trials, relative to congruent ones (Ricciardelli et al., 2002). This vouches for the unique role of the face and eyes in automatically activating a similar motoric program in the participant by mere observation (Román et al., 2018; Rugani & de Hevia, 2017; Suitner et al., 2017).

Faces and their gaze direction acquire added significance in the context of Posner-inspired cueing tasks. Recent research (Suitner et al., 2017) has shown that rightward oriented faces imply agency from left to right in line with the culturally established writing-reading system. This would suggest that face gazes as cues in a Posner-inspired cuing task would have an asymmetrical attentional influence. Rightward oriented faces would be expected to facilitate a stronger rightward attentional shift compared to a leftward attentional shift with oriented faces as cues.

Overview of the Present Experiments

Building upon the above line of research, we expected the reading and writing practices derived from the culturally established script direction to drive a biased scanning of external space. Across two studies we investigated the extent to which automatic attention orienting and subsequent target discrimination were shaped by visual social cues (i.e. faces presenting three distinct perspectives: left-facing, front-facing, right-facing). If the spatial bias found in the West is an attention-driving mechanism, then the robust congruency effect typically found in cueing tasks should be amplified for right-cue/right target pairs, over left-cue/left target pairs. This bias would be expected as a result of a culturally habitualized script effect and conflict with the prediction that symmetrical outcomes would result from a congruent target prime constellation, namely left-left and right-right.

In experiment 1, we relied on behavioral measures, namely response times, to investigate if distinct face orientations serve as attention orienting cues and affect target discrimination latencies. In experiment 2, we extended previous findings and introduced an objective process measure of eye movement to address the underlying processes that drive discrimination decisions.

Experiment 1

In experiment 1, photos of faces were presented when they were facing left vs. front vs. right in the middle of the monitor screen. These photos were chosen to serve as primes driving attention orienting cues and were expected to shape discrimination decisions in line with the SAB. We expected: 1) Shorter response times when the face position was congruent with the target letter position as compared to when face and target letter positions were incongruent; 2) The effect on 1) was expected to be amplified when cue-target pairs referred to the right, that is, right-facing (left-facing) primes were expected to produce shorter reaction times, when the target letter appears in the right (left) visual field; 3) No difference in discrimination latencies for targets on the left and right visual fields were expected when the prime was front-facing, and thus constituted the baseline condition; 4) In the absence of a target letter within the target sets, false detections should be congruent with the face position.

Results

Reaction Time and False Detections

Data for correct response times were analyzed. For obvious reasons, the no-target trials were not included in this analysis. In order to control for anticipatory and spurious responses, reaction times under 100 ms were excluded. A residual percentage (8.57%) of missing responses was observed across all data points.

We performed a linear mixed model analysis (LMM) which allowed us to control for the variance in response time introduced by the photo stimuli and the participants' individual differences (photo ID and participant ID). No severe violation of the homoscedasticity and normality principles were observed in the residual plots.

The LMM was conducted including the photo ID and participant ID as clustering factors, the reaction time as the dependent variable, and face orientation (left vs. front vs. right), target letter (left vs. right), and response interval (700 ms vs. 1000 ms vs. 1300 ms) as categorical independent variables. As fixed effects in the model, we considered the face orientation, target letter, and response interval as well as their second and third-order interactions. As random effects, we included random intercepts per participant and per photo. Moreover, the model was estimated using restricted maximum likelihood, and a Satterthwaite approximation of the degrees of freedom was considered. The LMM analysis was performed using the GAMLj module (Gallucci, 2019) implemented with the jamovi software (The jamovi project, 2019).

The LMM analysis ($R^2_{marginal}$ = .15; $R^2_{conditional}$ = .28) revealed a main effect of face orientation, F (2, 4255) = 37.24, p < .001, target letter, F (1, 4261) = 77.90, p < .001, and response interval, F (2, 4257) = 292.87, p < .001. Post-hoc comparisons with Bonferroni correction revealed that front-facing photos and right-facing photos (*M* = 542, *SE* = 12.7 and *M* = 545, *SE* = 12.6, respectively) gave rise to significantly shorter reaction times than left-facing primes (*M* = 596, *SE* = 12.7, *p*'s < .001). Different discrimination times were not observed between front-facing and right-facing faces (*p* = 1.000). Interestingly, the 700 ms interval (*M* = 476, *SE* = 12.8) produced faster response times than the 1000 ms and 1300 ms response intervals (*M* = 562, *SE* = 12.6 and *M* = 646, *SE* = 12.5, respectively; *p*'s < .001). Response times in the 1000 ms window were also significantly faster than those in the 1300 ms window (*p* < .001). Thus, the shorter the response window, the faster the discrimination. Additionally, target letters embedded on the right visual field (*M* = 536, *SE* = 12.4) were detected significantly faster than those on the left side (*M* = 586, *SE* = 12.3, p < .001).

We then turned to the second order interaction between face orientation and target location as it addresses directly our first prediction that congruent (vs. incongruent) cue-target pairs would improve discrimination performance, F (2, 4255) = 47.50, p < .001 (Figure 1). As expected, right oriented faces gave rise to significantly faster discrimination of targets on the right side (*M* = 482, *SE* = 13.5) relative to those on the left side of space (*M* = 608, *SE* = 13.6, *p* < .001). Front-facing faces did not generate different discrimination latencies across left (*M* = 542, *SE* = 13.5) and right presented targets (*M* = 543, *SE* = 13.6, *p* = 1.000), nor did left-facing faces (left target: *M* = 608, *SE* = 13.5; right target: *M* = 584, *SE* = 13.7, *p* = .216). We thus failed to observe the predicted effect on congruency pertaining leftward faces as the generated discrimination latencies did not statistically differ across target locations.

Additionally, and to address our second prediction of an imbalance in performance favoring the right(left)-sided targets following rightward (leftward) faces, we report the post-hoc comparison in discrimination latencies between left face – left target vs. right face – right target conditions. Results show a clear and significant asymmetry in performance between the two congruent conditions and favoring rightward cue-target pairs, t (4257) = 12.9945, p < .001.

A three-way interaction between face orientation, target letter and interval was also obtained, F (4, 4255) = 3.94, p = .003, although no predictions were made regarding the influence of the three time intervals on discrimination.

To ensure that hand dominance did not account for the observed rightward facilitation, we performed a paired samples t-test comparing the average reaction time of the *q* key press (*M* = 552.34, performed with the left index finger) and the *p* key press (*M* = 563.91, performed with the right index finger) across participants. Response latencies were not different when selecting *q* and *p* keys, *t* (44) = -1.660, *p* = .104, confirming that handedness did not drive the benefits on the right hemifield.

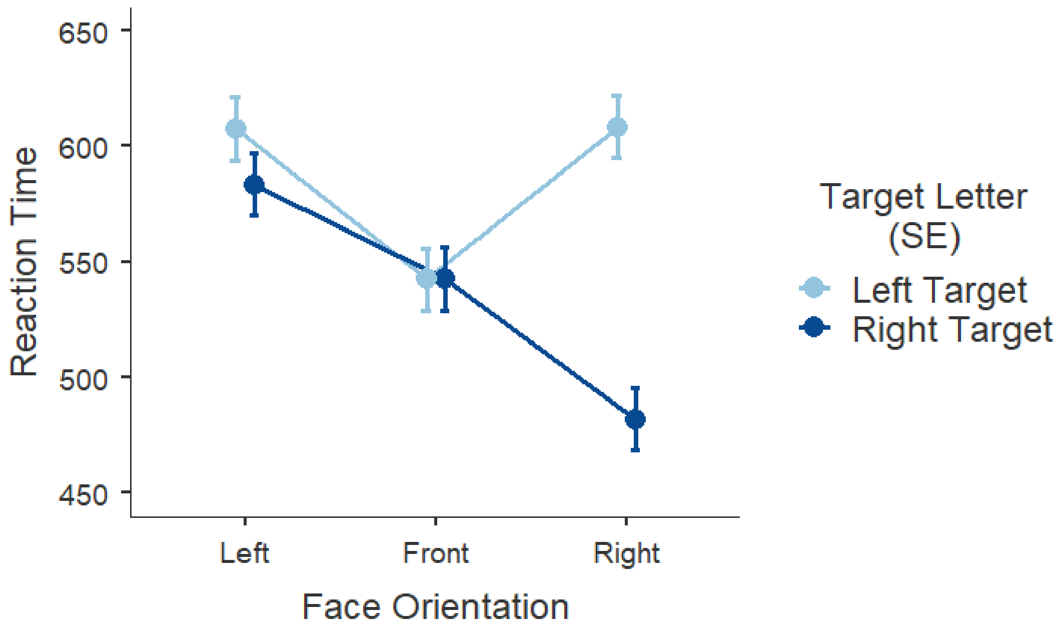

Figure 1. Mean response time (in milliseconds) as a function of face orientation of the cue, and target letter position. Error bars represent the standard error from the mean.

To investigate the trials without a target letter within the sets, we analyzed what we have called false detections (i.e. the selection of the left or right response keys) as predicted by the head orientations and the response intervals. To this end, given the dichotomous nature of the dependent variable, we performed a logistic mixed effects model (generalized mixed linear model for binomial outcomes). The present model predicted the proportion of the selection of the response key (0 = left key; 1 = right key) in terms of log odds with head orientation (left face vs. front face vs. right face) and response interval (700 ms vs. 1000 ms vs 1300 ms), and head orientation x response interval interaction as fixed effects. As cluster variables and random effects, we included random intercepts for participant ID and photo ID to control for dependencies in key selection driven by the variance introduced by the photos as well as the participants' interindividual differences. The logistic mixed effects model was performed using the GAMLj module (Gallucci, 2019) implemented with the jamovi software (The jamovi project, 2019). The model (n = 45; $R^2_{marginal}$ = .11; $R^2_{conditional}$ = .14) revealed that the probability of selecting a response key is different between head orientations (χ^2 = 153.308, df = 2, $p <$ .001). In contrast, the selection of the response key was not influenced by response interval (χ^2 = .634, df = 2, *p* = .728) nor by the interaction head orientation x response interval (χ^2 = 2.688, df = 4, *p* = .611).

We investigated the fixed parameters estimates for head orientation assuming left faces as the reference category. Positive regression slopes for both face comparisons indicate that, relative to left faces, front faces (β = .25, *SE* = .11, *z* = 2.216, *p* = .027) and right faces (β = 1.47, *SE* = .12, *z* = 11.853, *p* < .001) have a greater likelihood of inducing false detections to the right or inducing right key selection. By attending to the odds ratio, we can have a better perception of what these coefficients represent. The odds of a participant scoring 1 on the selection of response key, that is of pressing the right key, increases by a factor of 1.28 (CI [1.029, 1.59]) in frontal faces (compared to left faces). The influence of right faces can be seen in the odds ratio indicating that participants are 4.33 times more likely to press the right key (CI [3.398, 5.52]) in right faces relative to left faces. The remaining coefficients were not statistically significant (see Table 1 for detail on fixed effects parameter estimates).

Table 1. Fixed effects parameter estimates for the logistic mixed model predicting the proportion of false detections by head orientation and response interval. * *p* < .05, *** *p* < .001

				95% CI		
	Effect	**B**	**exp(B)**	**Lower**	**Upper**	***z***
Head Orientation1	Front – Left[a]	0.2460*	1.279	1.029	1.59	2.216
Head Orientation2	Right – Left	1.4656***	4.330	3.398	5.52	11.853
Response Interval1	1000 – 700[b]	0.0446	1.046	0.848	1.29	0.418
Response Interval2	1300 – 700	-0.0387	0.962	0.778	1.19	-0.357
Head Orientation1 x Response Interval1	Front – Left x 1000 – 700	0.1942	1.214	0.756	1.95	0.804
Head Orientation2 x Response Interval1	Right – Left x 1000 – 700	-0.1587	0.853	0.501	1.45	-0.584
Head Orientation1 x Response Interval2	Front – Left x 1300 – 700	0.2928	1.340	0.831	2.16	1.200
Head Orientation2 x Response Interval2	Right – Left x 1300 – 700	0.0680	1.070	0.626	1.83	0.249

Note: [a] Left is the reference category for the head orientation variable; [b] 700 ms interval is the reference category for the response interval variable

Finally, we explored post hoc comparisons for head orientation using the Bonferroni correction procedure (Figure 2). The probability of selecting the right key in front faces (.48) is significantly lower than in right faces (.76; $z = -9.92$, $p < .001$). The probability of selecting a right key in left faces (.42) does not differ from selecting the right key in front faces ($z = -2.22$, $p = .080$), suggesting that left and frontal head perspectives induce similar probability patterns of false detections. Critically, the probability of selecting the right key following the presentation of left faces is significantly more reduced than following right faces ($z = -11.85$, $p < .001$).

Thus, and predicted by our fourth hypothesis, in the absence of a target letter, false detections seem to be congruent with the face position. Specifically, the proportion of false detections on the left and right keys is significantly predicted by head orientation in that right faces induce right key clicking with a greater probability. Left and front faces are thus more likely to induce left key clicking, which is congruent with the direction they point towards (baseline faces lack directionality and are therefore expected to resemble performance for left faces). False detections seem to complement what was observed in response times by confirming that face primes do influence attention allocation towards their implied directionality. Taken together with the right-sided advantage observed in response latencies, false detections speak to the habitualized left-to-right eye trajectory and the underlying rightward bias it generates.

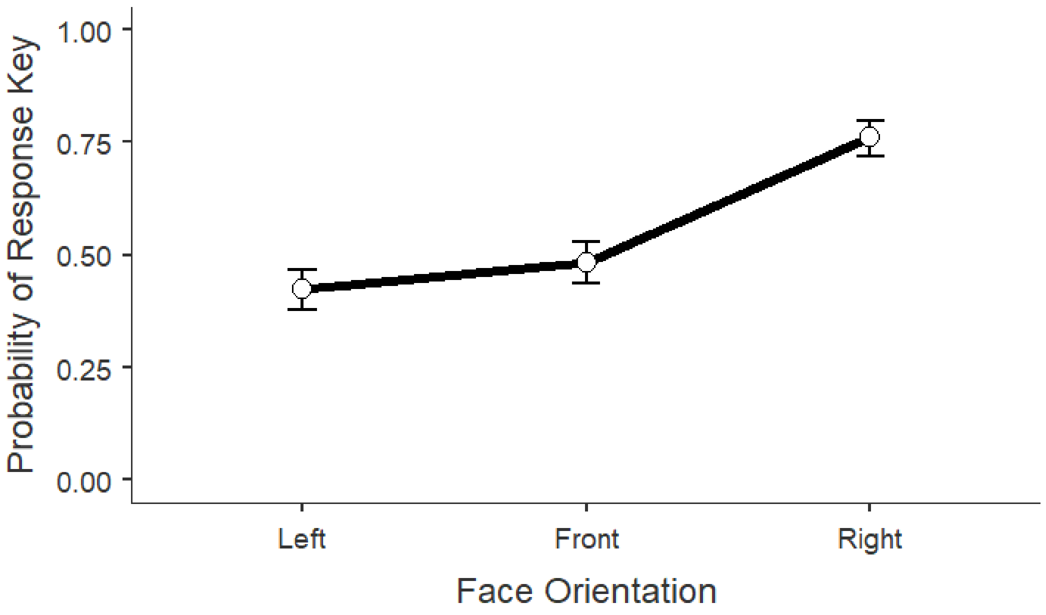

Figure 2. Proportion of false detections (0 = left key, 1 = right key) predicted by head orientation. Error bars represent 95% confidence intervals.

Experiment 2

This experiment extended the previous results and provided process evidence by tracking the participants' eye movements while performing the face cueing task. We measured overt attention (i.e., attention accompanied by oculomotor movements). Cue, target stimuli, and procedure were identical to Experiment 1. The design had two minor modifications: only the 1000 ms response interval was kept, and the target-absent condition was removed. This resulted in a 3 (Face orientation: left vs. front vs. right) x 2 (Target letter position: left vs. right) within participants manipulation. All measures, manipulations, and exclusions in this study are reported.

Aside from the expected replication of the previous experiment (i.e. response time), our main predictions were: 1) Head position would drive initial gaze movement, that is, the direction of the first saccade should be consistent with the face orientation of the prime; 2) When the face position is to the front, the automatic gaze direction is expected to be to the left. This is based on the assumption that front faces do not prime any directionality, hence they should induce the habitualized attention scanning path, starting from the left and moving to the right; 3) Earlier onset time for the first fixation in AOI for congruent compared to incongruent conditions, with an advantage for cue-target pairs pertaining to the right.

Results

Reaction Time

Data for correct response times were analyzed. Discriminations shorter than 100 ms were removed from the analysis. Missing responses were 21.47% across all data. To control for the variance introduced by the models' photos (photo ID), as well as the participants' interindividual differences (participant ID), a LMM was conducted. A visual inspection of the residual plots did not reveal any severe violation of the homoscedasticity or normality assumptions. The LMM was conducted including the photo ID and participant ID as clustering factors, the reaction time as the dependent variable, and face orientation (left vs. front vs. right), and target letter (left vs. right) as categorical independent variables. As fixed effects in the model, we considered the face orientation and target letter, as well as their interaction. As random effects, we included random intercepts per participant and per photo. The model was estimated using restricted maximum likelihood, and a Satterthwaite approximation of the degrees of freedom was considered.

The LMM ($R^2_{marginal}$ = .02; $R^2_{conditional}$ = .08) showed a main effect of face orientation, F (2, 5407) = 23.827, p < .001, with significantly faster responses following right-facing cues (*M*

= 707, *SE* = 6.55) than left (*M* = 732; *SE* = 6.55; $p < .001$) and front-facing cues (*M* = 737, *SE* = 6.50; $p < .001$). Response time following front and left-facing cues was not significantly different ($p = .918$). The interaction face orientation x target location, F (2, 5409) = 30.585, $p < .001$, revealed faster discrimination when cue and target where spatially congruent (Figure 3). Following a left-facing prime cue, target letters on the left (*M* = 718, *SE* = 7.29) were detected faster than targets on the right (*M* = 746, *SE* = 7.44; $p < .001$). Once again, following a right-facing face, this mean difference was amplified for the discrimination of targets on the right (*M* = 687, *SE* = 7.48) relative to the left (*M* = 727, *SE* = 7.25; $p < .001$). Frontal, neutral faces have resembled the pattern obtained for left-facing photos, albeit less pronounced. That is, front faces produced shorter response latencies on the left (*M* = 727, *SE* = 7.19) compared to the right side of space (*M* = 747, *SE* = 7.36; $p = .023$).

In order to investigate whether response times replicated the asymmetry in congruent conditions observed in Experiment 1, we report the post-hoc comparison for the performance between left face – left target and right face – right target conditions. Response times did replicate the results obtained in Experiment 1, t (5423) = 4.6152, $p < .001$, in that right targets following rightward faces were detected substantially faster than left targets following leftward faces.

Finally, we tested if handedness could have driven the obtained results. We compared averaged response times across participants when selecting the *q* key (*M* = 733.30, responded with the left finger) and the *p* key (*M* = 730.45, responded with the right finger), the latter coinciding with the dominant hand of most of the participants. We observed no differences in response times as a function of the hand used to respond, t (39) = -.520, $p = .606$.

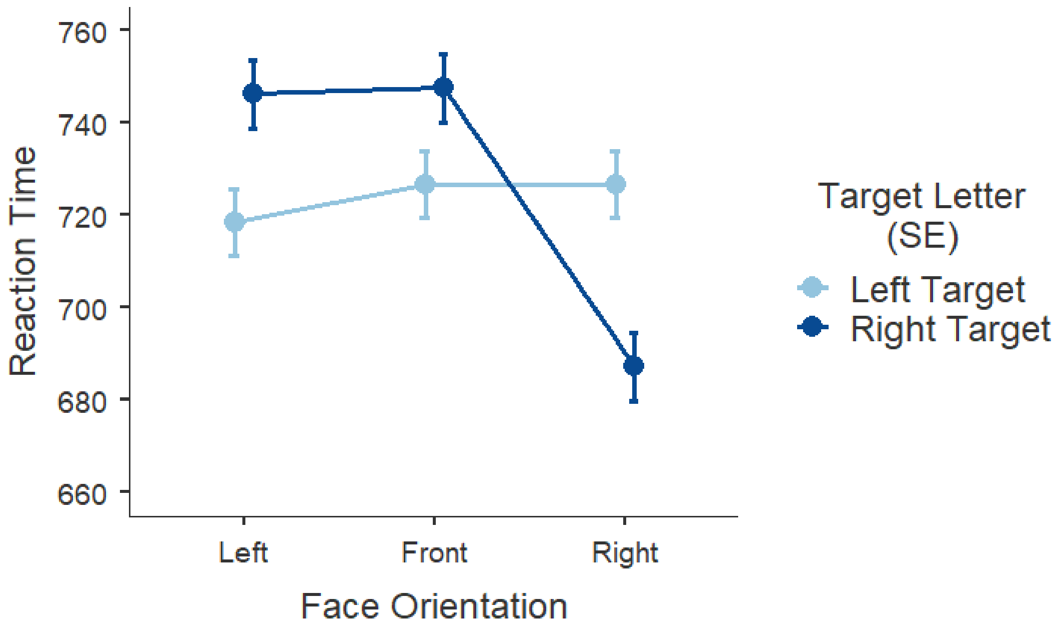

Figure 3. Mean response time (in milliseconds) as a function of face orientation of the cue and target letter position. Error bars represent the standard error from the mean.

Direction of the First Saccade

To examine initial gaze movement, that is, whether the face primes induced the expected orientation of attention, we analyzed the proportion of the first saccade made in each trial to the left and right sides of space as a function of the orientation of the face. The first saccade, as well as all the remaining gaze measures, were recorded from the moment the head cue had elapsed. The onset point for the first saccade was controlled for the screen's midpoint. The data were analyzed using a logistic mixed effects model. The model predicted the probability of the direction of the first saccade (0 = saccade to the left; 1 = saccade to the right) in terms of log odds. Head orientation (left face vs. front face vs. right face) was entered as a fixed effect. Participant ID and photo ID were included as random effects.

The model (n = 40; $R^2_{marginal}$ = .03; $R^2_{conditional}$ = .20) revealed that first saccades were not randomly distributed across left and right space, that is, they were shaped by the head orientation of the faces (χ^2 = 238, df = 2, p < .001). Taking left faces as the reference category, we can observe that front faces are less likely to induce rightward saccades although not significantly so (β = -.03, SE = .05, z = -.569, p = .570). Conversely, the positive regression slope for right faces, compared to left faces, suggests that these face primes are more likely to trigger saccades to the right (β = .70, SE = .05, z = 13.106, p < .001). In fact, the odds ratio indicates that right (vs. left) faces increase the likelihood of initially looking towards the right by a factor of 2 (*CI* [1.807, 2.23]). Detailed parameter estimates can be found in Table 2.

Table 2. Fixed effects parameter estimates for the logistic mixed model predicting the proportion of the direction of the first saccade by head orientation. *** $p < .001$

				95% CI		
	Effect	**B**	**exp(B)**	**Lower**	**Upper**	***z***
Head Orientation	Front - Left	-.0299	.971	.875	1.08	-.569
Head Orientation	Right – Left	.6959***	2.006	1.807	2.23	13.106

Note: Left is the reference category for the head orientation variable.

The post hoc comparisons using the Bonferroni procedure confirm that front faces have a lower probability (.42) of giving rise to saccades to the right than right faces (.60; $z = -13.657$, p < .001). Likewise, left faces (.42) are also less likely to induce saccades to the right than right faces ($z = -13.106$, $p < .001$). Mimicking the pattern observed in the measure of reaction time, front-facing faces resembled the initial gaze distribution observed for left-facing faces ($z = .569$, $p = 1$) (Figure 4).

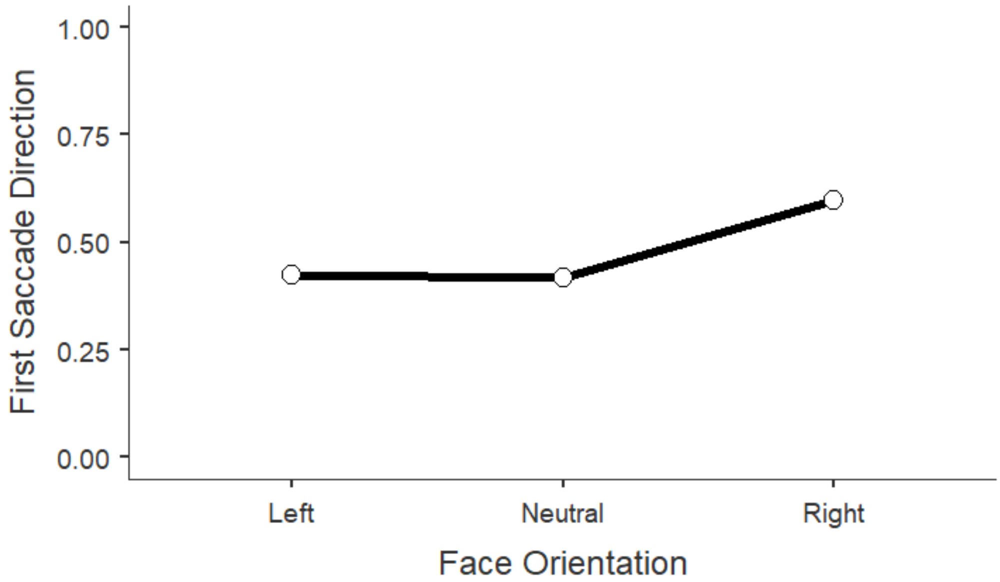

Figure 4. Proportion of the first saccade direction (0 = left saccade, 1 = right saccade) predicted by head orientation.

First Fixation Onset

In the previous analysis we confirmed that face primes induce attention towards their implied directionality. The next analysis was to test if there is a rightward attentional bias driving gaze movement. To observe this habitualized bias we tested the time to first fixation which indicates how early in the trial participants' gaze lands on the left and right located interest areas. Trials on which the eye-tracker lost track of the eye position were discarded (1.8% across conditions). We defined two rectangular areas of interest (AOI) corresponding to the two five-letter target sets (left AOI, right AOI) subtending the degrees of visual angle mentioned above.

We performed a LMM including the photo ID and the participant ID as clustering factors, the first fixation onset as the dependent variable, and face orientation (left vs. front vs. right), and AOI (left vs. right) as categorical independent variables. As fixed effects in the model, we considered the face orientation and AOI, as well as their interaction. As random effects, we included random intercepts per participant and per photo. The model was estimated using restricted maximum likelihood, and a Satterthwaite approximation of the degrees of freedom was considered.

The LMM ($R^2_{marginal} = .001$; $R^2_{conditional} = .20$) revealed a significant interaction between face orientation and AOI, F (2, 8076) = 39.76042, $p < .001$ (Figure 5). Both left and frontal face perspectives produced a similar pattern regarding the time it took to land the first fixation on the AOI around the target sets. This difference was more salient for left faces which generated earlier first fixations on the congruently located target area, that is the left AOI compared to the right AOI (M = 239, SE = 10.2; M = 260, SE = 10.4, respectively; $p < .001$). Front faces also gave rise to a slight advantage for earlier fixations on the left AOI (M = 244, SE = 10.2) than on the right AOI (M = 262, SE = 10.5; $p = .004$). As hypothesized, following a face cue averted rightward, participants attended earlier to the right AOI (M = 229, SE = 10.2) relative to the left AOI (M = 269, SE = 10.4; $p < .001$). In fact, participants attended the right AOI earliest, when the cue that preceded was a face oriented rightward, which is in line with our hypothesis.

The direct comparison of time to first fixation did not differ for fixations landing on the left AOI following left faces versus fixations landing on the right AOI following right face cues, t (8048) = 2.318, $p = .307$.

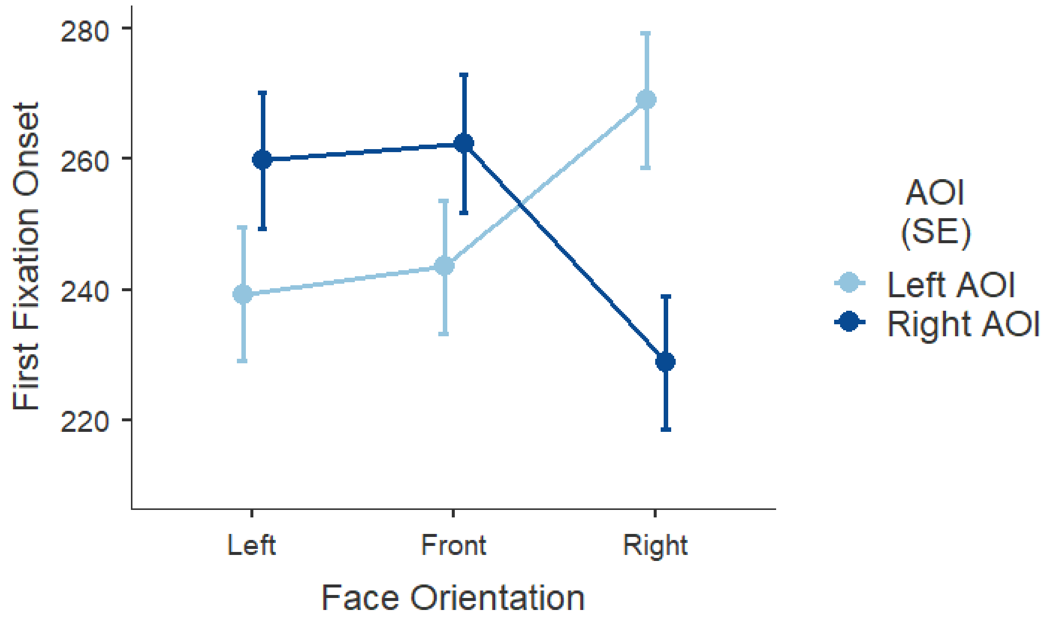

Figure 5. Mean time to first fixation (in milliseconds) as a function of face orientation of the cue and AOI. Error bars represent the standard error from the mean.

Discussion

In the present set of studies, we found visual performance to benefit from the habitualized reading and writing practices. As predicted, faces and their gaze direction as cues were found to have an asymmetrical attentional influence. Rightward oriented faces facilitated a stronger rightward attentional shift compared to the leftward attentional shift manifested with leftward oriented faces as cues. The two studies underscore the premise that rightward stimuli (i.e. aligned with script direction) preferentially engage human attention, hence triggering both biased discrimination latencies (experiments 1-2) and oculomotor movements (experiment 2).

In Experiment 1, which relied on behavioral measures alone, we did not observe the typical congruency effect on target detection speed reported in cueing tasks. Instead, irrespective of the time window for a response, only rightward faces gave rise to shorter latencies on right-located targets, relative to left-located ones. Contrary to an overwhelming body of literature showing otherwise (for a review see (Friesen & Kingstone, 1998)) , leftward faces did not generate the expected advantage in response times for targets located on the left hemifield. That is, they did not accelerate search time for left-sided targets. In fact, targets located on the left hemifield gave rise to very similar patterns of response latencies when paired with both left and rightward face primes. Thus, the advantage for the right side of space seemed to arise only for combinations of rightward oriented primes paired with targets on the right hemifield as shown in direct comparisons. As expected, front-facing faces produced no differentiation in performance for target discrimination across hemifields, as these primes were absent of any directionality and therefore constituted our baseline condition. However, the similar performance following frontal faces across left and right targets does not necessarily imply symmetry. In fact, across all dependent measures (e.g., reaction times, first fixation onset) subtle differences can be observed between left and right hemifields. This means that front faces did not produce a mirrored performance towards left and right space but displayed a minor skewness. Biological determinants account for this result since the fusiform face area (FFA), defined by its selectivity for face perception, typically displays some lateralization (Kanwisher et al., 1997).

However, conclusions from Experiment 1, namely on the potential rightward bias in human attention scanning, should be draw with caution. Experiment 1 carries significant limitations by examining manual performance alone (i.e. response time) although traditional accounts on cueing tasks take behavioral performance as the signature response for attention allocation (Frischen et al., 2007). These conclusions are naturally bounded by the variables one can control in such a setup, which exclude participants oculomotor movements as a direct check for visual asymmetries.

These results are best interpreted in conjunction with supporting evidence provided by the false detections measure. A higher probability of obtaining false detections on the right (higher proportion of clicks in the right key) was found when participants were presented with right faces. In addition, the proportion distribution of false detections tells us that the response key was congruent with the directionality implied by the face prime. At the very least, this effect does suggest that facial primes affect attention orienting and shape consequent peripheral detection. Naïve to the actual manipulation in target-absent trials, participants unknowingly reported having seen the target in the hemifield corresponding to the orientation of the prior face cue. We believe that the right discrimination advantage obtained in response times, sustained by the congruency in false detections, hints at a systematic rightward asymmetry in the visual system.

In Experiment 2, we carefully monitored participants' gaze movements and ensured that the face prime was attended to prior to target onset. Behavioral responses clearly demonstrate the robust congruency effect across both congruency conditions, an effect that was only obtained for the right congruent condition in experiment 1. A direct comparison between cue-target congruent pairs replicates the asymmetric right-side advantage obtained in Experiment 1. It is worth noting that the cueing effects produced by the frontal cues have overall resembled those observed for left-facing cues. Nevertheless, across measures of response time and first fixation onset in Experiment 2, for instance, it is possible to observe that front faces did not exactly mimic the performance obtained for leftward faces but have instead assumed intermediate values between left and right face perspectives. Although it is clear the pattern of effects follows that of leftward faces, front faces appear to have established an effect of their own, i.e. similar to but less pronounced than left faces. Arguably, the rationale behind the effect of frontal primes may come across as counterintuitive. It is reasonable to speculate that presenting baseline faces centrally has anchored the starting point of eye movement which one would assume to progress towards the right as in the case of reading, producing a carry-over effect and benefits on the right space. However, the systematic effect of front faces favoring the left space across the measures we report seems to suggest otherwise. We have hypothesized that since front faces are devoid of any inherent directionality and therefore should not prime lateralized attention. We propose that front faces, in lacking relevant directional content with the potential to trigger attention, are in fact comparable to an absence of prime. In this scenario, attention is likely to begin at center but to retrocede to the habitualized starting position of reading and writing routines (i.e. left) – although less markedly than in left faces.

Furthermore, a close inspection of participants' gaze movements nicely revealed that initial saccadic behavior was congruent with the face prime. In a similar yet more reliable way than what false detections had already shown in Experiment 1, this report reiterates the capacity that face primes have to direct attention. We show that observed probabilities differ reliably from a uniform 50:50 distribution in left vs. right saccades, with right faces triggering rightward saccades to a greater probability than front- and left-facing faces. The first saccadic movement was also launched faster to the right region of space and therefore landed earlier in the right (versus left) located AOI following a rightward face.

Together, this set of studies provides evidence that attention is not equally distributed across hemifields. Biological influences of hemispheric specialization must surely exert some pressure on the lateralization of attention and should not be overlooked. Other genetic predispositions such as handedness, however, cannot account for our results. We did not observe differences in responding as a function of the left and rightly located targets on the keyboard. Thus, our data seems to suggest that attention is, to some extent, guided by prior expectations that are based on how language script unfolds, and movement progresses in space.

Although face cues were task-irrelevant, we show that a brief exposure to rightward faces suffices to counteract the expected spontaneous left-anchoring tendency for attention allocation. The proposal that faces both capture and hold attention and that gaze direction is best interpreted in conjunction with other cues such as head orientation is far from new (Bindemann et al., 2007; Langten et al., 2000; Loomis et al., 2008). Previous research has successfully shown that reading and writing routines largely contribute to the mapping of abstract concepts (i.e. time) which in turn biases orientation of spatial attention and primes congruent left/right responses (Ouellet, Santiago, Funes, et al., 2010). Similarly, symmetry in conceptual congruency effects between abstract (i.e. past/future, good/bad, high/low status) and concrete (i.e. space, brightness, weight, temperature) domains can be modulated by attentional cueing (Santiago et al., 2012) and is linked to the exposure to asymmetric linguistic patterns and the degree to which these patterns are themselves asymmetric (Lakoff & Johnson, 1980).

Here, we take this rationale one step further by demonstrating that not only attention is spatially distributed following the left-to-right movement continuum but that there is an asymmetrical advantage for attending to the right side of space provided people are congruently cued. Although the leftward and rightward face manipulations used here refer to a generic abstract property – motion – attentional allocation did not produce bidirectional, similarly sized effects. In our view, our results, namely that visuomotor performance was not uniform but favored the right space, are due to the overlap with the habitualized rightward reading and writing routines of participants. This conclusion is supported by the fact that we have overruled handedness and stimulus-response compatibility as contributing factors. The observed right-sided discrimination facilitation is also beyond the stimulus-response compatibility effects found in other studies (Ouellet, Santiago, Israeli, et al., 2010) since the task at hand distinctively required target identification rather than mere location detection. Furthermore, we demonstrate that this tilted attention scanning goes well beyond the concrete activities of reading and writing and can be attained through means of very fundamental, language-absent, social cues like laterally averted faces. Indeed, rightward (versus leftward) faces have been reported to convey greater agency given that agency perceptions are largely drawn from the left-to-right movement continuum (Suitner et al., 2017). Arguably, perceptions inferred from our right profiles, although gender counterbalancing was controlled for, may have also added upon the left-right scanning practices of our participants, therefore partially accounting for the present results.

Evidently, the present research carries a number of limitations. First, to accurately draw conclusions on the underlying processes driving the attentional bias and asymmetric priming effects, we lack a sample of participants from right-to-left speaking countries whose attention is expected to flow on the opposite direction. Although reversal effects, albeit weaker, have been found for social representation of people (Maass, Suitner, & Nadhmi, 2014; Maass & Russo, 2003), aesthetic judgements (Smith et al., 2020), and memory performance (Bettinsoli et al., 2019), they have not been observed with the specific paradigm we tested here. Bidirectional readers could also provide important insight on the extent to which the attentional bias operates. In this case, the degree of the attentional bias is expected to be either negligible or a function of the more salient cultural background. While we believe that the systematic imbalance in responding behavior favoring rightward over leftward space (and therefore countering the biological proneness for the left anchoring of attention) suffices to argue that the convention for text direction exerts some form of attention control (as others have shown before us), only data from a sample habitualized with the reverse convention in this specific task would ensure indisputable evidence.

This work has important applied implications. These are particularly salient for the advertisement and marketing domains and for practitioners in fields relying on person perception, namely politics. These findings speak to the importance of tailoring the representation in space of any stimuli implying a sense of motion (i.e. cars, bicycles) according to the prevalent script on the receivers' given culture. The placement of logos or other stimuli with non-dynamic properties also ought to consider the asymmetric distribution of attention in order to guarantee optimal capture of attention, processing fluency, memory, and recall (Chae & Hoegg, 2013; Hernandez et al., 2017).

Altogether, these findings advance prior research by revealing that a fundamental cognitive process (i.e. attention), which was initially conceived as 'culture free' is susceptible to culturally maintained habits such as scanning practices derived from written text convention and has implications on how the environment is explored.

Methods

Experiment 1

Participants

Forty-five undergraduate students (37 females; M_{age} = 23.2, SD = 7.4; six self-reported left-handers) were recruited in exchange for course credit. Sample size was determined a priori using G*Power software package for within-subjects ANOVA with 80% power to detect an effect size of $\eta_p^2 = 0.191$ or similar as in earlier studies (Farias et al., 2016). Participants were screened to normal or corrected-to-normal visual acuity. All participants were born in Portugal and the first language they had learned to read and write was a left-to-right language, that is, Portuguese. None of the participants had knowledge of or extended exposure to right-to-left languages. The experiment complied with the relevant guidelines of the institution and has thus received full ethics clearance from the Ethics Committee of ISPA – Instituto Universitário. An informed consent was collected from all participants.

Cues

Forty-two high-quality photos of unfamiliar faces previously piloted were used as cue stimuli. The face models signed an informed consent clearly stating that the photos in the different perspectives would feature in an online open access publication and would incorporate a photo dataset to be made available for research purposes. The photos were split into three sets of fourteen faces with fully averted profile to the left, the right, and front-facing perspective. Each set was counterbalanced for gender (7 male, 7 female). In order to avoid familiarity with the stimuli, the same face was never presented in two different face perspectives to a given participant. Six additional photos were used during the training phase following the same counterbalancing schema. The faces were presented with 10x10 cm and subtended 9.53° of visual angle. All face cues were centrally presented against a medium gray background.

Targets

The target stimuli consisted of two sets of five letters (4.77°) simultaneously presented to the left and the right side of the screen midpoint at ±13.31° eccentricity, that is, in the near peripheral visual field. The target letter was either a *q* or a *p* embedded in one of the two letter sets (4 confounding letters and 1 target letter on one side of the screen; 5 confounding letters on the other) or no target letter (only distractors) was presented on both sides. Both confounding letters and target letters were kept constant across the experiment and their position within the target set was varied randomly across trials. This target setup, that is one of two possible target letters appearing on either side, required discrimination rather than mere detection (Collings & Eaton, 2016). This prevented participants to assume target location if the target was not present in the letter set they first attended to. Thus, if participants gaze towards the right and the target is not present, then it necessarily means that the target letter is on the left. However, this information is not sufficient to infer which of the two target letters (*p* or *q*) is the correct one.

Moreover, by introducing a target-absent condition, we were able to explore the extent to which false detections are a function of distinct head orientations.

Apparatus

The task was programmed using E-prime 2.0 (copyright 2010, Psychology Software Tools, Inc.). The stimuli were displayed on an Asus VX238H 23” Full HD LED monitor (1920x1080) and the task was run on a Dell OptiPlex 755 with a refresh rate of 60 Hz. The monitor was placed at the viewing distance of 60 cm. A Cedrus RB-540 response pad recorded participants response times and error rates. Participants responded to the target by pressing the left key (*q*) or right key (*p*).

Design

The design was a 3 (face orientation: left vs. front vs. right) x 3 (target letter position: left vs. right vs. no target) x 3 (response interval: 700 ms vs. 1000 ms vs. 1300 ms) within-subjects' factors. All measures, manipulations, and exclusions in this study are disclosed.

Valid (congruent), invalid (incongruent) and target-absent trials were kept constant across the experiment so that face cues were non-informative of target location. All factor combinations were equiprobable and presented equally often throughout the experiment. The front-facing faces constituted the baseline and had the exact same target distribution. Target type *q* and *p* was counterbalanced within face orientation and validity.

Procedure

The task was administrated in multiple sessions in the research laboratory of the University. Participants were instructed to attend to the target to generate a response because faces were uninformative of the target location. The general instruction was a speed-accuracy one. Participants placed their index fingers on the respective response keys and were asked to press them as soon as they located the target letter *p* or *q*. Importantly, participants were not told that in some trials there would be no target.

The task consisted of a variation of an attention orienting paradigm. The trial sequence commenced with a fixation cross (0.3° × 0.3°) at the center of the display for 1000 ms followed by the presentation of the face cue for 150 ms. A blank screen for stimulus onset asynchrony followed the cue and lasted 150 ms. The two letter strings were presented on the left and right sides of the display prompting an answer by the participant. Participants were requested to answer within a brief response window (see below). If participants failed to discriminate the target letter within the given response window, then it constituted a missing trial. A screen with a feedback message followed for 800 ms informing participants about the accuracy of their response or instructing them to be faster in case that the response time had elapsed. A blank screen was then presented for 500 ms and a new trial began (Figure 6).

The response window durations varied between 700 ms, 1000 ms, and 1300 ms. The reason for this manipulation was two-fold. For one, preliminary pilots revealed that the task was highly demanding upon selective attention and carried a high perceptual load due to the large the number of items to be processed. Second, these intervals were chosen to allow us to explore within participants how reaction time in discrimination evolves over time. By relying on three response length intervals, we could pinpoint whether discrimination occurs at the same point in time or not, despite the interval given to respond.

Each block consisted of 42 trials. The experiment comprised 6 blocks resulting in a total of 252 trials, 84 per response window. The three response intervals were randomized across trials. Prior to the main experiment, participants completed 12 practice trials. The average completion time of the experiment was 20 minutes.

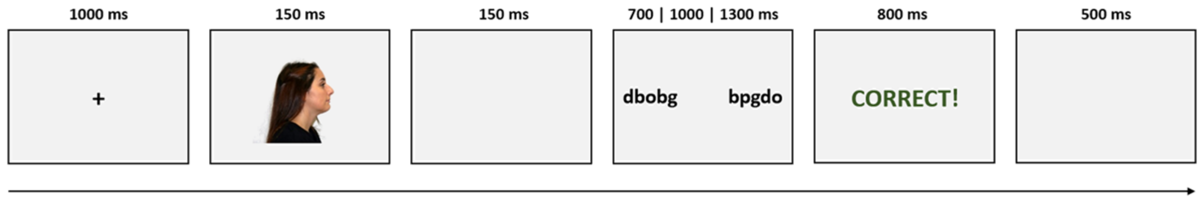

Figure 6. Procedure schema with an example of a cue-target rightward congruent trial.

Experiment 2

Participants

Forty participants (36 female, M_{Age} = 25.35, *SD* = 8.13; nine self-reported left-handed) took part in the experiment in return for course credit or a commercial voucher. All participants were screened to normal or corrected-to-normal visual acuity. All participants were native Portuguese speakers. Informed consent was collected from all participants and the experiment was performed in accordance with the relevant guidelines and approved by the Ethics Committee of ISPA – Instituto Universitário.

Apparatus

The task was programmed using Experiment Builder (Version 1.10.1630, SR Research, 2016). The stimuli were displayed on an Asus VX238H 23" Full HD LED monitor (1920x1080) driven by a Dell OptiPlex 755 with a refresh rate of 60 Hz. An Eyelink 1000 plus eye tracker (SR Research) with a sampling rate of a 1000 Hz was calibrated to the participants' dominant eye, but viewing was binocular. Calibration was performed with the standard nine-point calibration procedure, resulting in a reported interval of 0.25° - 0.5° average accuracy for all points. Calibration was repeated if the error at any point was higher than 1°. A chin and forehead rest were used to restrict participants' head movements and to control for the viewing distance to the screen at 60 cm. Responses were collected using the keys *q* and *p* on a standard keyboard.

Procedure

The task was administrated in single sessions in a dimly lit room in the research laboratory of the University. The general procedure, block composition and counterbalancing were the same as in Experiment 1. However, the fixation cross marking the beginning of each trial was replaced by a drift check, which only triggered the next trial if participants focused on it for a minimum of 1000 ms. Each drift check prior to trial onset was manually accepted by the experimenter. This procedure ensured that the starting point of eye movement for each trial was in the center of the display, thus preventing attention to be oriented elsewhere prior to cue onset. Between each of the six blocks of 42 trials, participants took a self-paced break followed by a recalibration. The experiment lasted approximately 40 minutes.

References

Abele, A. E., & Wojciszke, B. (2014). Communal and agentic content in social cognition: A dual perspective model. *Advances in Experimental Social Psychology*, *50*, 195–255. https://doi.org/10.1016/B978-0-12-800284-1.00004-7

Afsari, Z., Keshava, A., Ossandón, J. P., & König, P. (2018). Interindividual differences among native right-to-left readers and native left-to-right readers during free viewing task. *Visual Cognition*, *26*(6), 430–441. https://doi.org/10.1080/13506285.2018.1473542

Afsari, Z., Ossandón, J. P., & König, P. (2016). The dynamic effect of reading direction habit on spatial asymmetry of image perception. *Journal of Vision*, *16*(11), 8. https://doi.org/10.1167/16.11.8

Axelrod, V., Bar, M., & Rees, G. (2015). Exploring the unconscious using faces. *Trends in Cognitive Sciences*, *19*(1), 35–45. https://doi.org/10.1016/j.tics.2014.11.003

Benwell, C. S. Y., Thut, G., Learmonth, G., & Harvey, M. (2013). Spatial attention: Differential shifts in pseudoneglect direction with time-on-task and initial bias support the idea of observer subtypes. *Neuropsychologia*, *51*(13), 2747–2756. https://doi.org/10.1016/J.NEUROPSYCHOLOGIA.2013.09.030

Bettinsoli, M. L., Maass, A., & Suitner, C. (2019). The first, the least and the last: Spatial asymmetries in memory and their relation to script trajectory. *Memory and Cognition*, *47*, 229–239. https://doi.org/10.3758/s13421-018-0861-1

Bindemann, M., Burton, A. M., Langton, S. R. H., Schweinberger, S. R., & Doherty, M. J. (2007). The control of attention to faces. *Journal of Vision*, *7*, 15. https://doi.org/10.1167/7.10.15

Blom, S. S. A. H., & Semin, G. R. (2013). Moving events in time: Time-referent hand-arm movements influence perceived temporal distance to past events. *Journal of Experimental Psychology: General*, *142*(2), 319–322. https://doi.org/10.1037/a0029026

Bulf, H., De Hevia, M. D., Gariboldi, V., & Cassia, V. M. (2017). Infants learn better from left to right: A directional bias in infants' sequence learning. *Scientific Reports*, *7*(2437). https://doi.org/10.1038/s41598-017-02466-w

Chae, B., & Hoegg, J. (2013). The future looks "right": Effects of the horizontal location of advertising images on product attitude. *Journal of Consumer Research*, *40*(2), 223–238. https://doi.org/10.1086/669476

Chatterjee, A., Southwood, M. H., & Basilico, D. (1999). Verbs, events and spatial representations. *Neuropsychologia*, *37*(4), 395–402. https://doi.org/10.1016/S0028-3932(98)00108-0

Chen, Y. C., & Spence, C. (2017). Hemispheric asymmetry: Looking for a novel signature of the modulation of spatial attention in multisensory processing. *Psychonomic Bulletin and Review*, *24*, 690–707. https://doi.org/10.3758/s13423-016-1154-y

Collings, R. D., & Eaton, L. G. (2016). Does target object processing affect reaction times in simple detection spatial cueing tasks? *Perceptual and Motor Skills*, *122*(2), 395–410. https://doi.org/10.1177/0031512516639800

Driver, J., Davis, G., Ricciardelli, P., Kidd, P., Maxwell, E., & Baron-Cohen, S. (1999). Gaze perception triggers reflexive visuospatial orienting. *Visual Cognition*, *6*(5), 509–540. https://doi.org/10.1080/135062899394920

Farias, A. R., Garrido, M. V., & Semin, G. R. (2013). Converging modalities ground abstract categories: The case of politics. *PLoS ONE*, *8*(4), e60971. https://doi.org/10.1371/journal.pone.0060971

Farias, A. R., Garrido, M. V., & Semin, G. R. (2016). Embodiment of abstract categories in space. . . grounding or mere compatibility effects? The case of politics. *Acta Psychologica*, *166*, 49–53. https://doi.org/10.1016/j.actpsy.2016.03.002

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin & Review*, *5*(3), 490–495. https://doi.org/10.3758/BF03208827

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, *133*(4), 694–724. https://doi.org/10.1037/0033-2909.133.4.694

Fuhrman, O., & Boroditsky, L. (2010). Cross-cultural differences in mental representations of time: Evidence from an implicit nonlinguistic task. *Cognitive Science*, *34*(8), 1430–1451. https://doi.org/10.1111/j.1551-6709.2010.01105.x

Gallucci, M. (2019). *GAMLj: General analyses for linear models*.

Gevers, W., Reynvoet, B., & Fias, W. (2003). The mental representation of ordinal sequences is spatially organized. *Cognition*, *87*(3), B87–B95. https://doi.org/10.1016/S0010-0277(02)00234-2

Hernandez, M. D., Wang, Y., Sheng, H., Kalliny, M., & Minor, M. (2017). Escaping the corner of death? An eye-tracking study of reading direction influence on attention and memory. *Journal of Consumer Marketing*, *34*(1), 1–10. https://doi.org/10.1108/JCM-02-2016-1710

Hietanen, J. K. (2002). Social attention orienting integrates visual information from head and body orientation. *Psychological Research*, *66*(3), 174–179. https://doi.org/10.1007/s00426-002-0091-8

Jahn, G., Knauff, M., & Johnson-Laird, P. N. (2007). Preferred mental models in reasoning about spatial relations. *Memory and Cognition*, *35*, 2075–2087. https://doi.org/10.3758/BF03192939

Jewell, G., & McCourt, M. E. (2000). Pseudoneglect: A review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia*, *38*(1), 93–110. https://doi.org/10.1016/S0028-3932(99)00045-7

Kanwisher, N., McDermott, J., & Chun, M. M. (1997). The fusiform face area: A module in human extrastriate cortex specialized for face perception. *Journal of Neuroscience*, *17*(11), 4302–4311. https://doi.org/10.1523/jneurosci.17-11-04302.1997

Kermani, M., Verghese, A., & Vidyasagar, T. R. (2018). Attentional asymmetry between visual hemifields is related to habitual direction of reading and its implications for debate on cause and effects of dyslexia. *Dyslexia*, *24*(1), 33–43. https://doi.org/10.1002/dys.1574

Lakoff, G., & Johnson, M. (1980). The metaphorical structure of the human conceptual system. *Cognitive Science*, *4*, 195–208. https://doi.org/10.1016/S0364-0213(80)80017-6

Langten, S. R. H., Watt, R. J., & Bruce, V. (2000). Do the eyes have it? Cues to the direction of social attention. *Trends in Cognitive Sciences*, *4*(2), 50–59. https://doi.org/10.1016/S1364-6613(99)01436-9

Langton, S. R. H., & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Visual Cognition*. https://doi.org/10.1080/135062899394939

Loomis, J. M., Kelly, J. W., Pusch, M., Bailenson, J. N., & Beall, A. C. (2008). Psychophysics of perceiving eye-gaze and head direction with peripheral vision: Implications for the dynamics of eye-gaze behavior. *Perception*, *37*(9), 1443–1457. https://doi.org/10.1068/p5896

Maass, A., Pagani, D., & Berta, E. (2007). How beautiful is the goal and how violent is the fistfight? Spatial bias in the interpretation of human behavior. *Social Cognition*, *25*(6), 833–852. https://doi.org/10.1521/soco.2007.25.6.833

Maass, A., & Russo, A. (2003). Directional bias in the mental representation of spatial events: Nature or culture? *Psychological Science, 14*(4), 296–301. https://doi.org/10.1111/1467-9280.14421

Maass, A., Suitner, C., & Deconchy, J. P. (2014). *Living in an asymmetrical world: How writing direction affects thought and action*. Psychology Press Ltd.

Maass, A., Suitner, C., & Nadhmi, F. (2014). What drives the spatial agency bias? An Italian-Malagasy-Arabic comparison study. *Journal of Experimental Psychology: General*, *143*(3), 991–996. https://doi.org/10.1037/a0034989

Mansfield, E. M., Farroni, T., & Johnson, M. H. (2003). Does gaze perception facilitate overt orienting? *Visual Cognition, 10*(1), 7–14. https://doi.org/10.1080/713756671

McCourt, M. E., & Jewell, G. (1999). Visuospatial attention in line bisection: Stimulusmodulation of pseudoneglect. *Neuropsychologia*, *37*(7), 843–855. https://doi.org/10.1016/S0028-3932(98)00140-7

Mills, M., Smith, K. B., Hibbing, J. R., & Dodd, M. D. (2014). The politics of the face-in-the-crowd. *Journal of Experimental Psychology: General*, *143*(3), 1199–1213. https://doi.org/10.1037/a0035177

Ouellet, M., Santiago, J., Funes, M. J., & Lupiáñez, J. (2010). Thinking about the future moves attention to the right. *Journal of Experimental Psychology: Human Perception and Performance*, *36*(1), 17–24. https://doi.org/10.1037/a0017176

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (2010). Is the future the right time? *Experimental Psychology*, *57*(4), 308–314. https://doi.org/10.1027/1618-3169/a000036

Pecchinenda, A., Pes, M., Ferlazzo, F., & Zoccolotti, P. (2008). The combined effect of gaze direction and facial expression on cueing spatial attention. *Emotion*, *8*(5), 628–634. https://doi.org/10.1037/a0013437

Pollatsek, A., Bolozky, S., Well, A. D., & Rayner, K. (1981). Asymmetries in the perceptual span for Israeli readers. *Brain and Language*, *14*(1), 174–180. https://doi.org/10.1016/0093-934X(81)90073-0

Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology*, *32*(1), 3–25. https://doi.org/10.1080/00335558008248231

Posner, M. I., & Cohen, Y. (1984). Components of visual orienting. *Attention and Performance*. https://doi.org/10.1162/jocn.1991.3.4.335

Rayner, K. (1998). Eye movements in reading and information processing: 20 years of research. *Psychological Bulletin*, *123*(3), 372–422. https://doi.org/10.1037/0033-2909.124.3.372

Ricciardelli, P., Bricolo, E., Aglioti, S. M., & Chelazzi, L. (2002). My eyes want to look where your eyes are looking: Exploring the tendency to imitate another individual's gaze. *NeuroReport*, *13*(7), 2259–2264. https://doi.org/10.1097/00001756-200212030-00018

Rinaldi, L., Di Luca, S., Henik, A., & Girelli, L. (2014). Reading direction shifts visuospatial attention: An interactive account of attentional biases. *Acta Psychologica*, *151*, 98–105. https://doi.org/10.1016/j.actpsy.2014.05.018

Román, A., El Fathi, A., & Santiago, J. (2013). Spatial biases in understanding descriptions of static scenes: The role of reading and writing direction. *Memory and Cognition*, *41*, 588–599. https://doi.org/10.3758/s13421-012-0285-2

Román, A., Flumini, A., Lizano, P., Escobar, M., & Santiago, J. (2015). Reading direction causes spatial biases in mental model construction in language understanding. *Scientific Reports*, *5*, 18248. https://doi.org/10.1038/srep18248

Román, A., Flumini, A., & Santiago, J. (2018). Scanning of speechless comics changes spatial biases in mental model construction. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*, 20170130. https://doi.org/10.1098/rstb.2017.0130

Rugani, R., & de Hevia, M. D. (2017). Number-space associations without language: Evidence from preverbal human infants and non-human animal species. *Psychonomic Bulletin and Review*, *24*, 352–369. https://doi.org/10.3758/s13423-016-1126-2

Sajjacholapunt, P., & Ball, L. J. (2014). The influence of banner advertisements on attention and memory: Human faces with averted gaze can enhance advertising effectiveness. *Frontiers in Psychology*, *5*, 166. https://doi.org/10.3389/fpsyg.2014.00166

Santiago, J., Ouellet, M., Román, A., & Valenzuela, J. (2012). Attentional factors in conceptual congruency. *Cognitive Science*, *36*(6), 1051–1077. https://doi.org/10.1111/j.1551-6709.2012.01240.x

Sato, W., Okada, T., & Toichi, M. (2007). Attentional shift by gaze is triggered without awareness. *Experimental Brain Research*, *183*(1), 87–94. https://doi.org/10.1007/s00221-007-1025-x

Shaki, S., Fischer, M. H., & Petrusic, W. M. (2009). Reading habits for both words and numbers contribute to the SNARC effect. *Psychonomic Bulletin and Review*, *16*(2), 328–331. https://doi.org/10.3758/PBR.16.2.328

Shaki, S., & Gevers, W. (2011). Cultural characteristics dissociate magnitude and ordinal information processing. *Journal of Cross-Cultural Psychology*, *42*(4), 639–650. https://doi.org/10.1177/0022022111406100

Smith, A. K., Duerksen, K. N., Gutwin, C., & Elias, L. J. (2020). Lateral biases in aesthetic and spatial location judgments: differences between tasks and native reading directions. *Laterality*, *25*(1), 5–21. https://doi.org/10.1080/1357650X.2019.1577433

Smith, A. K., & Elias, L. J. (2013). Native reading direction and corresponding preferences for left- or right-lit images. *Perceptual and Motor Skills*, *116*(2), 355–367. https://doi.org/10.2466/23.24.PMS.116.2.355-367

Sosa, Y., Teder-Sälejärvi, W. A., & McCourt, M. E. (2010). Biases of spatial attention in vision and audition. *Brain and Cognition*, *73*(3), 229–235. https://doi.org/10.1016/j.bandc.2010.05.007

Spalek, T. M., & Hammad, S. (2004). Supporting the attentional momentum view of IOR: Is attention biased to go right? *Perception and Psychophysics*, *66*, 219–233. https://doi.org/10.3758/BF03194874

Spalek, T. M., & Hammad, S. (2005). The left-to-right bias in inhibition of return is due to the direction of reading. *Psychological Science*, *16*(1), 15–18. https://doi.org/10.1111/j.0956-7976.2005.00774.x

Suitner, C., & Maass, A. (2016). Spatial agency bias: Representing people in space. *Advances in Experimental Social Psychology*, *53*, 245–301. https://doi.org/10.1016/bs.aesp.2015.09.004

Suitner, C., Maass, A., & Ronconi, L. (2017). From spatial to social asymmetry: Spontaneous and conditioned associations of gender and space. *Psychology of Women Quarterly*, *41*(1), 46–64. https://doi.org/10.1177/0361684316676045

The jamovi project. (2019). *jamovi* (version 1.0).

von Hecker, U., Klauer, K. C., Wolf, L., & Fazilat-Pour, M. (2016). Spatial processes in linear ordering. *Journal of Experimental Psychology: Learning Memory and Cognition*, *42*(7), 1003–1033. https://doi.org/10.1037/xlm0000220

Yokoyama, T., Sakai, H., Noguchi, Y., & Kita, S. (2014). Perception of direct gaze does not require focus of attention. *Scientific Reports*, *4*, 3858. https://doi.org/10.1038/srep03858

Zwickel, J., & Melissa, L. H. V. (2010). How the presence of persons biases eye movements. *Psychonomic Bulletin and Review*, *7*, 257–262. https://doi.org/10.3758/PBR.17.2.257

Chapter IV.
Two cultural processing asymmetries drive spatial attention

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Abstract

Cultural routines, such as orthographic direction, channel attention orientation. Left-to-right (LR) language scripts induce a rightward bias, and right-to-left (RL) scripts, a leftward bias. Here, we further document this bias by showing its interaction with spatially grounded time concepts. We used a spatial cueing task to test whether script direction and the grounding of time in Portuguese (LR, Exp. 1) and Arabic (RL, Exp. 2) shape visuomotor performance in target discrimination. Temporal words (e.g., tomorrow, yesterday) were presented as cues in two modalities: visual (Exp. 1-2) and auditory (Exp. 1). Gaze movement (Exp. 1) and speed of discrimination decisions (Exp. 1-2) of targets presented to the left or right hemifields were assessed. As predicted, modalities, the interaction between target location and time concepts was significant. Additionally, LR participants detected the target on the right hemifield faster after a future word than the target on the left hemifield after a past word cue. In contrast, RL participants detected the target on the left hemifield faster when the cue word was a future word than the target on the right hemifield cued by a past word. In both modalities, the initial eye-gaze movement (Exp. 1) was responsive to the cue's time referent, further establishing that time orients attention. A further asymmetry was observed in the first fixation onset, which landed earlier on the target set that matched habitualized spatial routines. We conclude that scanning regularities are shaped by writing habits and bodily grounded categorical features.

Keywords

Spatial bias; Language Script; Visual attention; Time; Eye-tracking.

Introduction

Different features of language drive visuospatial attention in different conventionalized spatial dimensions. For instance, visual word cues such as *up*, *down*, *left*, and *right* drive spatial attention consistent with their semantic meaning. Upcoming stimuli appearing in the indicated locations are processed faster (e.g., Cristescu et al., 2006; Ho & Spence, 2005; Hommel et al., 2001). Reading and writing practices are another organizing convention contributing to the systematicity of visuospatial attention (Spalek & Hammad, 2005; Suitner & Maass, 2016). In 'Western' languages like English, reading and writing unfolds from left to right. In contrast, in languages such as Arabic or Hebrew, these processes unfold from right to left. These habitualized cultural standards influence scanning routines and establish an implicit yet preferential eye trajectory that generalizes to the scanning of visual objects. For instance, they shape the visual exploration of artwork (Chokron & De Agostini, 2000), agentic perceptions from faces (Mendonça et al., 2020a), or scanning preferences of soccer goals and action film clips (Maass et al., 2007). On the other hand, temporal events are organized on a LR or RL horizontal timeline depending on whether samples come from English or Hebrew linguistic communities (Fuhrman & Boroditsky, 2010).

We report two studies here. They have samples from contrasting cultures, namely one that has a habitualized left-right (LR) writing and reading direction and the other a habitualized right-left (RL) writing and reading tradition. The studies were designed to examine how attention and gaze movement are related to detection latencies, with a modified spatial cueing paradigm. Critically, the cues used in this paradigm are instances of an abstract category (time: 'yesterday', 'tomorrow'). This allows us to test the joint influence of two sources of bias on attention and gaze movement, and detection latencies as driven by: (1) spatial associations [left-right in European languages; and right-left in Arabic language], due to habitualized cultural habits of writing and reading. Thus, language script (LR vs. RL) drives attention consistent with the habitual movement direction (e.g., Bettinsoli et al., 2019; Maass & Russo, 2003; Mendonça et al., 2020b; Rinaldi et al., 2014) and (2) habitualized horizontal grounding of time concepts (Casasanto & Boroditsky, 2008; Santiago et al., 2007; Torralbo et al., 2006; Weger & Pratt, 2008).

Background and Rationale

Time is grounded in space. For instance, when reading and writing, we leave prior information behind, establishing a natural movement-space correlation that maps time in a script-consistent pattern (Casasanto, 2014). Time has been shown to activate spatial associations along the horizontal continuum (Blom & Semin, 2013; Boroditsky, 2011; Lakens et al., 2011). Temporal events are organized on a LR or RL horizontal timeline depending on whether samples come from English or Hebrew linguistic communities (Fuhrman & Boroditsky, 2010). Past terminology is anchored where writing typically begins: On the left for LR speakers and on the right for RL speakers. Consequently, future-related terms are anchored on the opposite end of the horizontal continuum: on the right for LR speakers and on the left for RL speakers (Ouellet, Santiago, Israeli, et al., 2010; Torralbo et al., 2006).

Consider a stimulus presentation in which two 5-letter strings (one of which containing a target letter) presented simultaneously to the left and right hemifields are preceded by the presentation of a time related central cue (e.g., yesterday, tomorrow) that anchors the starting position of gaze movement. If the cultural attention bias is correct, one would expect attention to progress from the center in a script-coherent direction (rightward for LR speakers and leftward for RL speakers). Therefore, cue words would speed up detection times and facilitate gaze movements if: (a) the cue word implies a reference to the hemifield that is consistent with writing habits (e.g., tomorrow; right hemifield advantage for LR speakers and left hemifield advantage for RL speakers) and (b) the target letter is embedded in the letter string located on the hemifield congruent with the indication of the word cue (right string for LR speakers and left string for RL speakers). The asymmetry that the culturally driven attention bias introduces is that the same detection speed and gaze advantage will not be to the same extent for the congruent conditions (e.g., detection of a target letter presented on the left after the cue word "yesterday" and presented on the right after the word cue "tomorrow" for LR speakers). Rather, it will be differentiated in favor of the cue-target pairs that reflect the habitual unfolding of perceptual scanning (target letter on the right after "tomorrow"). In the special combination of words, which also represent the time concept, we have two habituated cultural forces operating simultaneously. The first is words as language, activating orthographic habits, and the second is time concepts anchored on the horizontal past-future dimension. Both induce moving in the same cultural direction. By choosing cues that potentially bring together both the orthographic influence (script direction) and an abstract category (time), we introduce a critical experimental condition. In the case of a LR culture, future referent cues and targets on the right hemifield should be processed significantly faster than past referent cues and targets on the left hemifield, rather than the two being processed equally fast. This asymmetric advantage should be reversed in the case of RL cultures.

Additionally, presenting cue words in visual and auditory modalities would provide converging evidence of the process driving target detection and the function of cue words. If the pattern of speed and gaze outcomes in both modalities converges then one would infer that spatial bias is independent of the motor processes activated by reading. We expect both reading and hearing the cue word to yield similar effects (e.g., Lakens et al., 2011; Ouellet, Santiago, Israeli, et al., 2010).

Overview of the Present Research

The present studies were designed to examine how two habituated cultural forces facilitate the detection of targets presented to the left and right hemifields. As we suggested, the first is cues as words activating orthographic habits (Román et al., 2015), and the second cues as time concepts anchored on the horizontal past-future dimension (Santiago et al., 2007). To this end, we used a modified spatial cueing task (Mendonça et al., 2020b). In contrast to the typical balanced congruency effects, we predicted an asymmetric performance for congruent cue-target combinations. As the initial point of gaze movement is anchored in the center of the screen, attention was expected to progress in line with directional regularities, driven by orthographic habits (Suitner & Maass, 2016) as well as the horizontally grounded cue category, namely time. Thus, future words have a double processing advantage as cues. They facilitate target detection on the right hemifield for LR speakers (Exp. 1) and on the left hemifield for RL speakers (Exp. 2). This facilitation is expected to be revealed primarily by detection speed (Exp. 1-2) and the overall trajectory revealed by gaze movement (Exp. 1). We expected detection speed effects mirroring each other in the two languages (RL and LR). The asymmetry favoring the right or the left is, therefore, a product of the match between cultural scanning habits and horizontal semantic bias of the word cue.

Experiment 1

The first experiment used a LR speaking sample (Portuguese-speaking participants) to examine if the orientation of attention is driven by habitualized script direction and temporal cue words. The predictions were: 1) Overall, detection facilitation for congruent (versus incongruent) cue-target conditions, that is, shorter response times when temporal cue word connotation is consistent with the target letter location; 2) The specific effects predicted under 1) to be asymmetric between congruent cue-target pairs. In other words, the rightward influence of the spatial bias in LR languages should manifest itself in the case of future-related cue words when the target location is on the right hemifield relative to the response times of congruent past-related words and target letter on the left hemifield; 3) Initial gaze movement should respond to the temporal meaning of the word primes and script direction; 4) Time to first fixation in the area of interest (AOI) to be shorter for congruent compared to incongruent conditions, but revealing the asymmetric advantage for future cues and right AOI relative to past cues-left AOI pairings; 5) Visual and auditory modalities should reveal similar effects in the spatial mappings of time.

Method

Participants

Fifty-nine undergraduate students (40 females, M_{age} = 20.36, SD_{age} = 1.81; twelve self-reported left-handers) were recruited and compensated with course credit. Sample size was determined a priori using BUCSS R method (Anderson et al., 2017), adjusting sample size effects for uncertainty and publication bias correction (desirable level of assurance = .90; statistical power = .80) based on the effect size proposed for temporal priming effects (von Sobbe et al., 2019). Participants were screened to normal or corrected-to-normal visual acuity and had no hearing problems. They were self-declared native Portuguese speakers and had not spent any significant time in countries with right-to-left language scripts. All participants gave written informed consent for their participation. Both experiments were performed according to the Declaration of Helsinki and approved by the Ethics Committee of the host institution.

Cue Stimuli

Forty-eight time-related words were selected from a list of Spanish words used in similar tasks (Ouellet, Santiago, Israeli, et al., 2010; Torralbo et al., 2006). Words reflected a temporal continuum, that is, we selected a range of words pertaining to the far past and future as well as to the immediate past and future. Translation of words to Portuguese yielded 16 past-related words (e.g., “ontem” – “yesterday”), 16 future-related words (e.g., “amanhã” – “tomorrow”), and 16 words that were time-related but neutral in content (e.g., “dia” – “day”) (see Appendix 1 for the entire list). In each past and future-related set of 16 words, there were eight verbs inflected in either the past or future tense and eight temporal adverbs. In a previous validation study of the cue words, we presented the word list in a random order to Portuguese participants (n = 99). Participants were asked to move a sliding bar along a horizontal line to a position they thought best represented the time-related stimulus (0 = *far past*; 100 = *far future*). The words were grouped according to their mean ratings and semantic meaning (F (2, 47) = 235.347, p < .001; Past-oriented: M = 22.10, SD = 7.71; Neutral: M = 53.04, SD = 2.36: Future-oriented: M = 77.60, SD = 9.63; p’s < .001 between groups). Eight additional words were used for the practice block. Words were then converted to sound files using a text-to-speech application. Word duration did not differ across the time category of the words, F (2, 47) = .440, p = .647

(*M* = 992, *SD* = 171.02). Throughout the experiment, each word was presented twice visually and twice auditorily.

Target Stimuli

The target stimuli consisted of two five-letter strings. Only one string contained one of the two possible target letters – *q* or *p*. The remaining letters in the strings were distractors (four letters and the target letter on one side of the screen; five letters on the other). The two strings subtended 4.77° visual angle and were simultaneously presented in the near peripheral visual field at the left and right sides of the screen midpoint (±13.31° eccentricity). Therefore, it was not possible to process the target letter strings unless eye movements were made. Target and filler letters were kept constant across the experiment and were varied randomly within the five possible letter positions in the set. The task entailed a discrimination decision between two possible targets (*p* or *q* on the gamepad) and not a spatial decision regarding the side of the screen the target letter appeared, hence 1) circumventing a systematic overlap between response code and target letter location, and 2) preventing participants from inferring target location by merely gazing at one side of the screen. This discrimination setup ensures that performance cannot be accounted for by the target's spatial positioning (because the target’s location on the gamepad does not necessarily match its lateral positioning on the screen).

Apparatus and Display

The task was programmed in Experiment Builder (Version 1.10.1630, SR Research, 2016). The stimuli were displayed on an Asus VX238H 23” Full HD LED monitor (1920x1080) driven by a Dell OptiPlex 755 with a refresh rate of 60 Hz. Eye movements were calibrated and recorded from the dominant eye with a 1000 Hz Eyelink 1000 plus. A five-point calibration procedure was performed, resulting in a reported interval of 0.25° - 0.5° average accuracy for all points. Errors higher than 1° at any point led to a repetition in the calibration. A chin rest was used to restrict participants’ head movements and control the viewing distance to the screen at 60 cm. The task was presented against a medium gray background. Manual responses were collected using the keys marked as *q* and *p* on a standard gamepad. Auditory stimuli were presented via headphones.

Procedure

The task was administrated in single sessions at the university’s laboratory. Participants were asked to put on headphones and read the instructions. They were instructed to press the respective response key on the gamepad as soon as they detected the target letter embedded in one of the two five-letter strings. They were also informed that the words were non-informative of target location.

Each trial began with a 1000 ms drift check fixation (0.3° × 0.3°), which was gaze-contingent, therefore anchoring the participants' initial gaze movement at the center of the screen. The drift check was followed by the presentation of the word cue, either visually at the center of the screen for 1000 ms or auditorily via headphones for the duration of the sound file. Auditory stimuli were presented binaurally and equally loud to both auditory channels. During the auditory stimuli presentation, a gaze-contingent cross was presented in the center of the blank screen, ensuring participants' starting point of visual exploration prior to target onset. A blank screen followed the cue and lasted 150 ms. The two five-letter strings were then simultaneously presented to the left and right sides of the screen until participants responded or when 1000 ms had elapsed. After responding, participants received a feedback message informing them about the accuracy of their response or whether they were too slow. There were 192 trials in total, divided into two blocks, plus 16 practice trials. The number of congruent and incongruent trials was kept constant across the experiment; thus, word cues were uninformative of target location. All factors (modality, word category, and target location) were equally likely and presented in a counterbalanced order within a block. Participants took a 5-minute break between blocks, followed by a recalibration. The experiment took approximately 30 minutes to complete.

Results

Preliminary Analysis

Correct detections under 100 ms were excluded from the analysis to ensure that response times were not influenced by anticipatory responses (0.9%). Missing responses (trials where the time for responding elapsed) corresponded to roughly 31% of the total number of trials across participants.

Reaction Time

To address our hypothesis regarding detection facilitation for congruent (versus incongruent) cue-target conditions (H1) and an asymmetric performance favoring future-related words and targets located on the right side of space (H2), we performed a linear mixed model analysis (LMM). This analysis allowed us to control for the variance introduced by the word stimuli (word ID), the number of characters in the word (word length), and participants' individual differences (participant ID). We observed no severe violation of the homoscedasticity or normality assumptions in a visual inspection of the residual plots. The LMM was performed in jamovi software (version 1.2) with the GAMLj module.

The LMM included word ID, word length, and participant ID as clustering variables, prime modality (visual vs. auditory), word category (past-related vs. neutral vs. future-related) and target location (left vs. right) as categorical independent factors, and response time as the dependent variable. The model's fixed effects were prime modality, word category, target location, and their second- and third-order interactions. Random intercepts per word ID, word length and participant, were included. Any parameter with variance greater than 0 was left as random (Little et al., 2000). Word length presented a variance of 0 and was removed from the model. The model was estimated using restricted maximum likelihood, with a Satterthwaite approximation of the degrees of freedom.

The LMM analysis ($R^2_{marginal}$ = .02; $R^2_{conditional}$ = .08) revealed main effects of prime modality, *F* (1, 5790) = 21.83, *p* < .001, and word category, *F* (2, 41.4) = 20.97, *p* < .001. Post-hoc comparisons using Holm correction revealed that targets were detected significantly faster following visual (*M* = 673, *SE* = 5.07) relative to auditory word primes (*M* = 690, SE = 5.05, *p* < .001). Future-related words gave rise to shorter detection latencies (*M* = 664, *SE* = 5.47) than neutral (*M* = 688, *SE* = 5.48, *p* < .001) and past-related words (*M* = 693, *SE* = 5.45, *p* < .001). Past and neutral word cues did not produce significantly different response times (*p* = .312). The expected word category x target location interaction was significant, *F* (2, 41.4) = 24.48, *p* < .001 (Figure 1), indicating that congruent (vs. incongruent) conditions facilitate detection. Targets on the left hemifield were detected faster after past cue words were presented (*M* = 682, *SE* = 6.46) than targets on the right hemifield (*M* = 703, *SE* = 6.35, *p* = .044). Conversely, targets on the right hemifield benefited from future word cue presentation (*M* = 642, *SE* = 6.45) relative to targets on the left hemifield (*M* = 685, *SE* = 6.42, *p* < .001). Neutral words did not produce significant differences on detection of left (*M* = 685, *SE* = 6.45) and right targets (*M* = 690, *SE* = 6.46, *p* = 1.000) and hence did not prime any particular directionality.

Finally, to investigate the asymmetry between the congruent conditions reported above and favoring the rightward, script-coherent cue-target pairs, we report the post hoc comparison between past word - left target and future word - right target conditions. Results indicate unequivocal facilitation for congruent cue-target pairs that referred to the right (vs. left) side of space, *t* (43.9) = 5.8741, *p* < .001.

The remaining interactions were not statistically significant (*p*'s > .06). The fact that the third-order interaction did not reach statistical significance indicates that the congruency effect occurs irrespective of the sensory modality of presentation. As expected (H5), presenting temporal words visually or auditorily did not affect the interaction between word category and target location on response times. This indicates that the spatial representation of time converges across visual and auditory perception.

To rule out handedness as driving the cueing effects obtained, particularly if it was the overlap between the right-handedness of most participants with the right target location that was driving the rightward facilitation effects, we examined average response times that occurred when participants used the *q* key (M = 683.56, SE = 40.20; pressed with the left index finger) and the *p* key (M = 679.30, SE = 37.50; pressed with the right index finger). No difference in response time was observed when left and right hands were used to respond, t (58) = 1.072, p = .288.

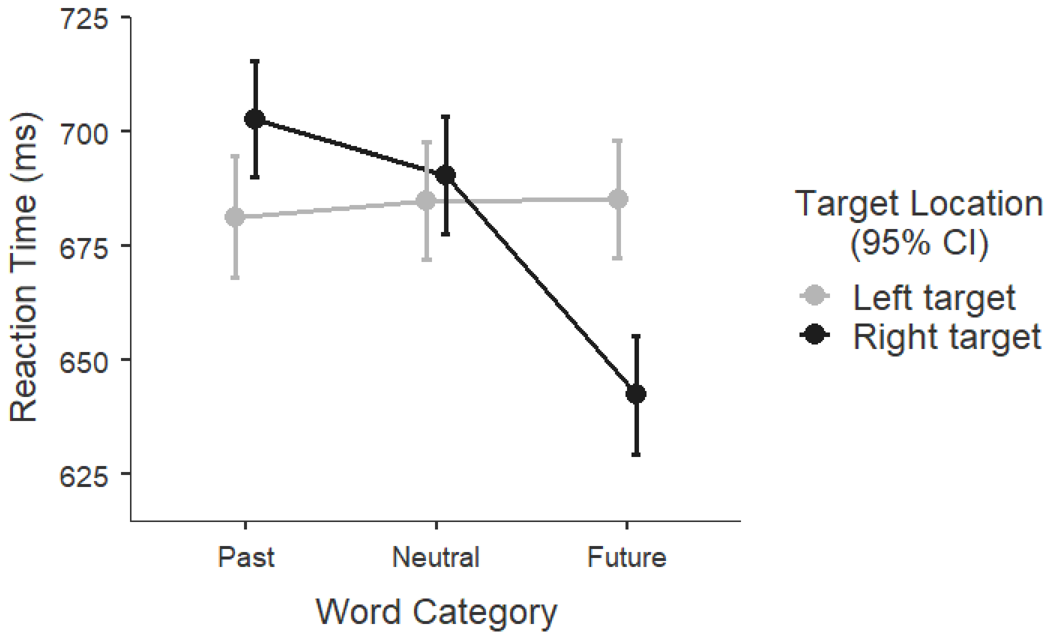

Figure 1. Mean reaction time (in milliseconds) as a function of the word category and the target letter location. Error bars represent 95% confidence intervals.

Eye-Tracking Data

We flagged and excluded trials in which the observer's gaze at fixation could not be verified to be within 1° of visual angle or for a minimum of 1000 ms (1.3% across all trials fixations). Fixations under 80 ms were excluded (4.90%), as were trials in which the tracker lost eye position (1.1%). We defined two rectangular areas of interest (AOI), which correspond to the target letter strings located on the left and right sides of the screen. Eye gaze measures were recorded from target onset.

Direction of the First Saccade

To examine initial gaze movement and confirm that the temporal words did guide attention, we examined the proportion of the first saccade in each trial (i.e. the oculomotor response to the prime) made to the left and right hemifields, as a function of the prime modality and word category. It is important to emphasize that participants' initial gaze movement was anchored in the center of the screen prior to target onset. Since binary data do not follow a normal distribution, we opted for a test based on the binomial distribution to model our data.

We analyzed first saccade direction in a logistic mixed-effects model to further control for the variance introduced by the word stimuli (word ID), the number of characters in the word (word length), and the participants' individual differences (participant ID). The model predicted the probability of the direction of the first saccade (0 = saccade to the left; 1 = saccade to the right) in terms of log odds. Prime modality (visual vs. auditory) and word category (past vs. neutral vs. future) and their interaction were entered as fixed effects. Target letter location was not included as a factor in this analysis because, as hypothesized (H3), we were interested in testing the first ocular response to the prime and attesting whether the temporal words were capable of priming attention. Intercepts for word ID, word length, and participant ID were included as random effects. Word ID and word length, as well as their intercepts, were removed from the model because their variance was 0 and hence these variables did not contribute to the model.

The model ($R^2_{marginal}$ = .02; $R^2_{conditional}$ = .22) showed that the first saccade in each trial did not follow an arbitrary distribution across hemifields but a preferential spatial scanning. First saccades were shaped by the directionality of the word category, χ^2 = 165.29, df = 2, p < .001. Taking the past-related words as the reference category, we observed a positive regression slope for future-related words, which suggests that these word primes are more likely to trigger saccades to the right space, β = .59, *SE* = .05, z = 11.65, p < .001, by a factor of 1.8 (*CI* [1.636, 1.997]). Neutral words also produced a positive regression slope, that is, they are also more likely to induce rightward saccades than the reference category (past words) although not significantly so, β = .05, *SE* = .05, z = 1.08, p = .279. Further, an interaction between prime modality and word category was observed, χ^2 = 16.804, df = 2, p < .001. We noted a significant negative regression slope for the comparison between auditory and visual primes and future- and past-related words, β = -.40, *SE* = .10, z = -3.98, p < .001. These results indicate that visual cues are more effective than auditory cues in driving rightward saccades following future words. The detailed parameter estimates can be found in Table 1.

Table 1. Fixed effects parameter estimates for the logistic mixed model predicting the proportion of the direction of first saccade by prime modality and word category. *** $p < .001$

				95% CI		
	Effect	**B**	**exp(B)**	**Lower**	**Upper**	***z***
Prime Modality	Auditory – Visual	-.03923	.962	.887	1.042	-.9510
Word Category	Neutral – Past	.05453	1.056	.957	1.166	1.0825
Word Category	Future – Past	.59190***	1.807	1.636	1.997	11.6531
Prime Modality x Word Category	Auditory - Visual x Neutral – Past	-.11221	.894	.734	1.089	-1.1139
Prime Modality x Word Category	Auditory - Visual x Future – Past	-.40248***	.669	.548	.815	-.3.9753

Note: Past is the reference category for the word category variable.

Post hoc comparisons using the Holm correction confirmed that past-related words have a lower probability (.45) of generating initial saccades to the right than future words (.60; z = -11.65, p < .001). Likewise, neutral words (.46) are also significantly less likely to trigger rightward initial saccades than future words (z = -10.59, p < .001). Similar to what we have already observed in the reaction time measure, neutral words gave rise to a comparable initial gaze distribution to the one observed for past-related words (z = -1.08, p = .279) (Figure 2). As for the significant interaction effect, auditory past words (.47) were less likely to evoke right saccades than auditory future words (.56; z = -5.48, p < .001) just like visual past words (.43) are less likely to trigger right saccades than visual future words (.63; z = -10.99, p < .001). These findings confirm that, across modalities, both past and future temporal primes did deploy automatic attention in a direction that is consistent with their semantic meaning (H3).

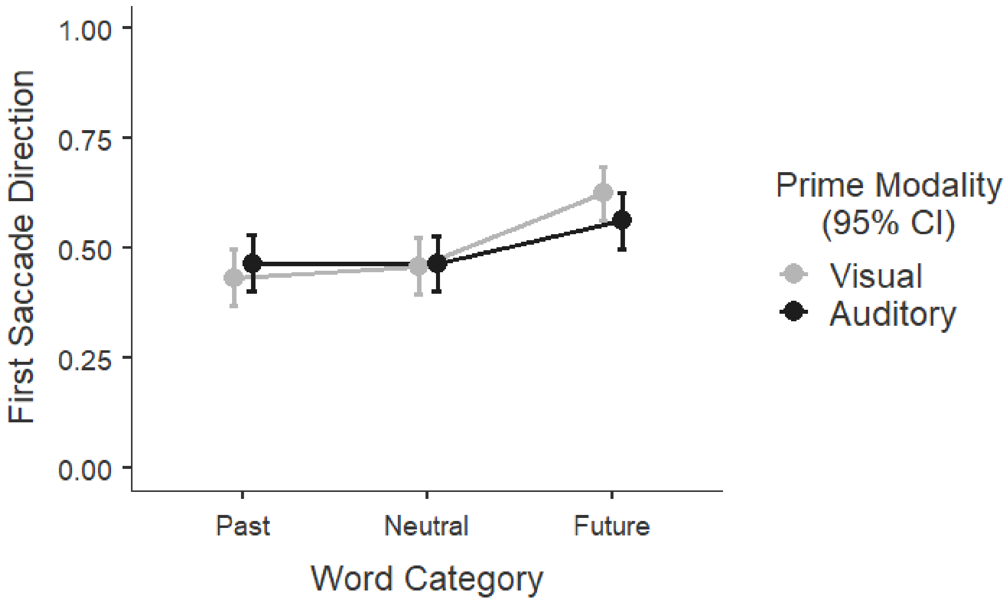

Figure 2. Proportion of the first saccade direction (0 = left saccade, 1 = right saccade) predicted by prime modality and word category. Error bars represent 95% confidence intervals.

First Fixation Onset

After confirming that temporal terms induce the expected orientation of attention, we investigated if there is, in fact, a rightward bias of attention. To this end, we tested if the first fixation onset, that is, the time in the trial the first fixation landed on the left and right areas of interest (AOI), was biased across modalities by rightward word stimuli (H4). Again, target location was left out of this analysis because we aimed to show that the initial gaze movement and resulting first fixation was biased towards the right region of interest, irrespective of whether the target was present or not. Due to a software error during the recording session, data from two participants are not reported in this analysis (n = 57).

A LMM analysis was conducted after a visual inspection of the plots revealing no significant violations to the normality and homoscedasticity assumptions. The model included word ID, word length, and participant ID as clustering variables, prime modality (visual vs. auditory), word category (past-related vs. neutral vs. future-related), and AOI (left vs. right) as categorical independent factors, and first fixation onset as the dependent variable. The model's fixed effects were prime modality, word category, and AOI, and their second- and third-order interactions. Random effects per participant, word ID, and word length were included to control for the variance these factors might introduce in first fixation onset measures. Word length and its intercept were removed from the model for having a variance of 0. The model was estimated using restricted maximum likelihood, with a Satterthwaite approximation of the degrees of freedom.

Results from the LMM analysis ($R^2_{marginal}$ = .01; $R^2_{conditional}$ = .09) converge with the previous manual responses by showing a main effect of word category, F (2, 45.3) = 30.49983, p < .001. Again, words with future connotation produced earlier first fixations (M = 198, SE = 4.15) than neutral (M = 218, SE = 4.15; p < .001) and past-relevant words (M = 216, SE = 4.15; p < .001). In line with what was previously observed, neutral words did not give rise to different first fixation onsets than past words (p = .415). An interaction between word category and AOI emerged, F (2, 10264.5) = 37.33751, p < .001. As predicted, first fixations landed earlier on the AOI that was congruent with the orientation induced by the temporal word (Figure 3). This means that participants' first fixation was launched earlier in the trial to the left AOI after a past-related word was presented (M = 207, SE = 4.48) than to the right AOI (M = 224, SE = 4.55, p < .001). Likewise, first fixations after words with a right referent, that is, future-related, reached the AOI located on the right earlier (M = 187, SE = 4.53) than on the left AOI (M = 210, SE = 4.50; p < .001). Time taken to first fixation after neutral words was virtually the same in the left (M = 215, SE = 4.48) and right AOI's (M = 220, SE = 4.54; p = .517), suggesting that these words do not strongly induce any directionality. The remaining interactions were not significant (p's > .09). Therefore, first fixations following temporal words reached their congruently located AOI's faster, and this effect was not differentiated between visual and auditory presentation (H5).

To address the proposed rightward asymmetry between congruent trials, a direct comparison between first fixation onset on the left AOI following past-oriented words and on the right AOI following future-oriented words, t (160) = 5.300, p < .001, confirmed that attention orientation benefits from rightward (vs. leftward) word stimuli, which overlap with the left-to-right scanning practices of our participants.

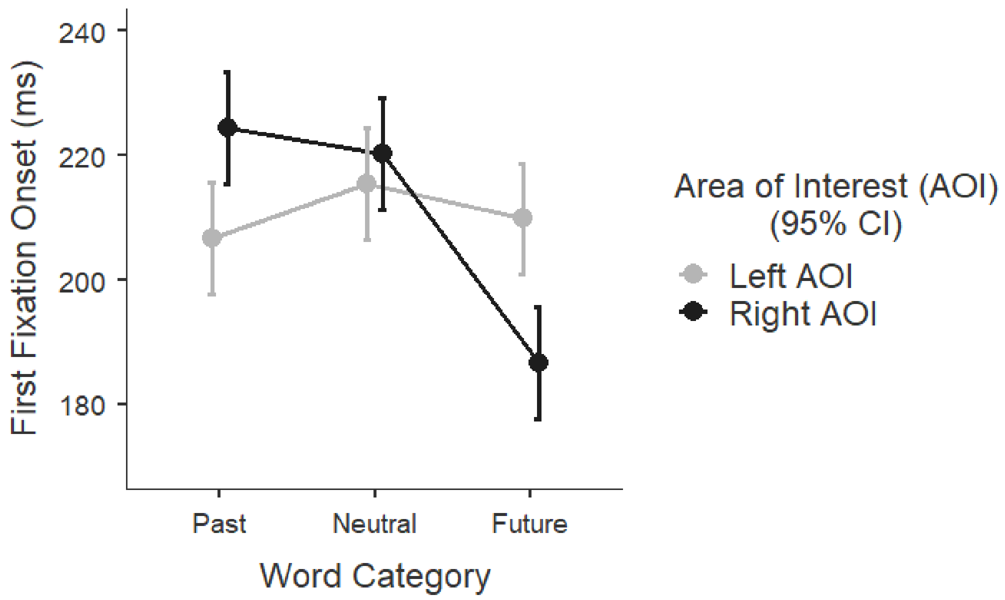

Figure 3. Mean time to first fixation (in milliseconds) as a function of word category and AOI. Error bars represent 95% confidence intervals.

Experiment 2

The second experiment was designed to examine the generality of the effects observed in Exp. 1 across a linguistic community with the opposite script direction - unfolding from right-to-left. Because Exp. 2 was collected online, it was not possible to provide gaze movement measures. Nevertheless, if we observe a reversal in time-space mappings and the proposed directional asymmetry observed in Exp. 1, then there are grounds for RL generalizations. In Exp.2, we presented cue words in the visual modality alone because, in remote settings, it is virtually impossible to guarantee that participants wear the headphones that are necessary to receive the auditory stimuli, control the volume of presentation, etc. We tested participants with the same cueing task, but with the temporal verbs and adverbs translated into Arabic. The aim was to unravel if the spatial mapping of time was reversed (i.e., past-right/future-left) and if leftward reading-writing habits produce a left-sided advantage. Because attention starts from the center and is assumed to progress leftward, the same future-related words should produce a lateralized facilitation but now on the left space. This would indicate that scanning routines influence lateralized spatial attention. The predictions in terms of behavioral performance were the same as in Exp. 1 - but mirrored. Target stimuli, procedure, and design were similar to Exp. 1.

Method

Participants

We recruited fifty-six (36 males, M_{age} = 27.44, SD_{age} = 7.06, four self-reported left-handed) that were compensated for their participation through the crowdsourcing platform Prolific Academic. Sample size was determined a priori (Anderson et al., 2017), adjusting sample size effects for uncertainty and publication bias correction (desirable level of assurance = .90; statistical power = .80) based on the effect size proposed for temporal priming tasks (von Sobbe et al., 2019). Participants gave their consent to participate, and the experiment was approved by the Ethics Committee of the host institution (see Appendix 2 for a detailed sample characterization).

Cues

Cues were the forty-eight temporal words used in Exp. 1. The word set was translated from English to Arabic by a native Arabic-speaking translator (see Appendix 3 for the entire word list). The word list was pretested in an Arabic-speaking sample recruited and compensated via Prolific Academic (n = 106, 63 males, M_{age} = 22.36, SD_{age} = 4.31). Participants were presented with each word at the center of the screen and asked to move the slider below it towards the left or right depending on whether they thought the word referred to the future (0 = *far future*) or the past (100 = *far past*). Words were grouped in three semantic categories according to their mean ratings (F (2, 47) = 636.698, p < .001; Past-oriented: M = 61.46, SD = 3.42; Neutral: M = 51.70, SD = 3.58; Future-oriented: M = 21.44, SD = 2.88; *p's* < .001 between groups). Words were randomly presented four times throughout the main experiment, two in each block.

Targets

Targets were the equivalents to the letters *q* and *p* marked on the standard Arabic keyboard (*q* = ض and *p* = ح). In each trial, only a ض (*q*) or a ح (*p*) was embedded in one of the two bilateral five-letter strings presented to the left and right sides of the screen. The distractor filler letters were the same across the experiment and randomized across trials. Because the task was conducted online, it was not possible to control for viewing distance to the screen nor ascertaining the dimensions of the screen in which the task was performed. Although we could not compute the degrees of visual angle that the target strings subtended, the strings were programmed to appear in the near peripheral visual fields. This peripheral presentation ensured that participants would not be able to discriminate the target unless lateralized gaze movements were made. The task could not be performed on mobile phones or tablets because these devices would compromise gaze movement direction.

Procedure

Participants were redirected from the recruitment platform Prolific Academic to Gorilla to perform the experiment. The experiment was programmed and ran in Gorilla Experiment Builder, a platform that provides tools for online behavioral research ensuring accurate and reliable online recording of reaction time measures (Anwyl-Irvine et al., 2020). Participants were first presented with informed consent. Upon agreement, they moved to the main task. They were asked to place the index fingers on the ض (*q*) and ح (*p*) keys before commencing the task. The general instruction was a speed-accuracy one. After the task was completed, participants filled in a brief questionnaire with demographic information and the variables described in Appendix 2. All the information (task invite, informed consent, instructions of the task, final questionnaire) was given in Arabic. Behavioral responses were recorded through participants' keyboards by pressing the keys marked ض (*q*) or a ح (*p*).

The overall spatial cueing task, number of trials, and counterbalancing schema were the same used in Exp. 1, with the variation of targets being presented only in the visual modality. The task had a self-paced break between blocks. On average, participants completed the experiment in 20 minutes.

Results

Preliminary Analysis

A visual inspection of the data revealed that six participants finished the experiment but did not produce any responses (all trials were missing responses). These participants were excluded from further analyses. Spurious responses below 100 ms were excluded (2.4%). Missing responses corresponded to 18% of trials. Response time was recorded from target onset.

Reaction time

We performed a LMM analysis on response times. As fixed effects, we included word category (past vs. neutral vs. future), target letter location (left vs. right), and their second-order interaction, and as cluster variables participant ID and word ID. We included random intercepts of word and participant ID. A visual inspection of the residual plots showed no severe violation of the homoscedasticity or normality assumptions. The model was estimated using restricted maximum likelihood with a Satterthwaite approximation of the degrees of freedom and was performed in jamovi software (version 1.2) with the GAMLj module.

The LMM ($R^2_{marginal}$ = .02; $R^2_{conditional}$ = .07) revealed a significant main effect of word category, F (2, 42.9) = 20.5814, p < .001. The overall effect of the temporal category of words replicated what was observed in Exp. 1. Future-related words (M = 666, SE = 5.58), gave rise to faster detections than past-words (M = 695, SE = 5.58; p < .001). The speed in response times generated by future words was higher than that induced by neutral words (M = 675, SE = 5.58, p = .058). Past-related words were significantly slower in triggering responses than neutral words (p < .001). Hence, neutral words have assumed intermediate values. To address our prediction for congruency between the words and the location of the targets, we report a significant interaction of word category x target location, F (2, 42.9) = 32.7104, p < .001 (Figure 4). We observed the typical congruency effect but now reversed compared to what was observed in Exp. 1. Past-related words produced faster detection on the right target string (M = 680, SE = 6.38) than on the left (M = 710, SE = 6.55; p < .001), indicating that RL participants map the past on right spatial coordinates. Future-related words which are spatially mapped on the left by RL speakers, produced faster detection on the left target string (M = 646, SE = 6.54) than on the right target string (M = 687, SE = 6.40; p < .001). As hypothesized and replicating what was observed across measures in Exp. 1, neutral words produced similar detection latencies on the left (M = 682, SE = 6.57) and right space (M = 669, SE = 6.38; p = .265).

Finally, we moved to examine whether there was an asymmetric performance between congruent conditions derived from leftward scanning habits, that is, if the future-related words accelerated performance in the left target string above past-related words in the right target string. To this end, we report the comparison between the detection latencies observed for the two congruent conditions (future word – target left versus past word – target right), t (42.9) = -5.328, p < .001. The results indicate that words with a leftward connotation (i.e. future-related) that imply the same flow of attention as that imposed by reading-writing activities produce advantages in detecting the target on the left more so than past-related words did on their corresponding target location (i.e. right).

To ensure that handedness could not account for the left-sided advantage (although the majority of participants reported higher right-hand skill), we compared response times as a function of the response key used to respond, namely responses given by the ض (q) key (responded with the left hand) and by the ح (p) key (responded with the right hand). A paired samples t-test showed no difference in response times when left and right hands were used to detect targets, t (49) = .951, p = .346.

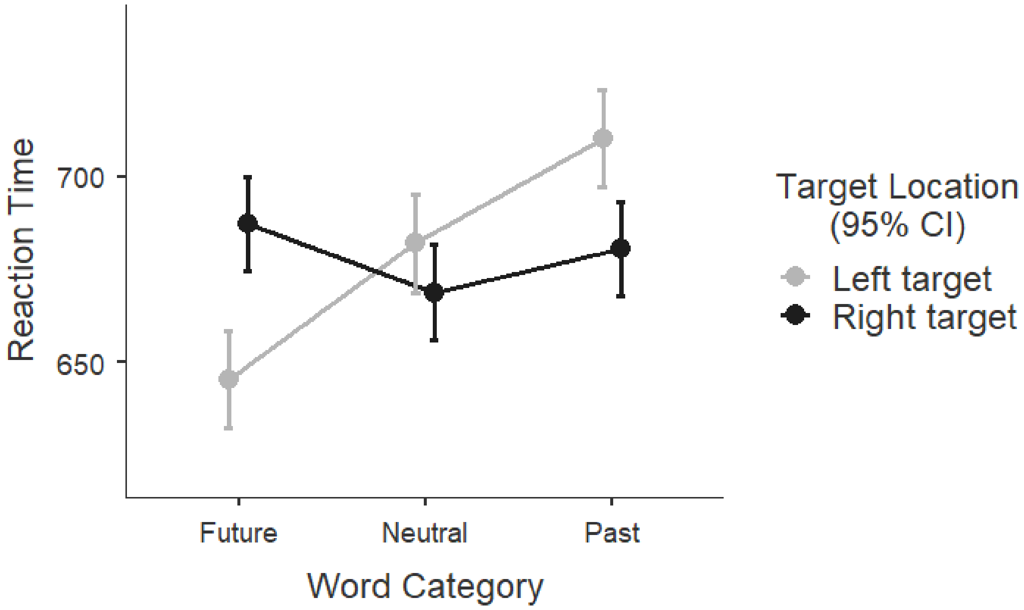

Figure 4. Mean reaction time (in milliseconds) as a function of the word category and the target letter location. Error bars represent 95% confidence intervals.

Discussion

The two experiments we report here were conducted with two cultural samples with opposite reading and writing directions. The first experiment was conducted with RL habitualized Portuguese participants. The second experiment was performed with participants who predominantly read and write in Arabic. The behavioral results across the two experiments yielded a remarkably similar pattern, albeit a mirror reflection of the pattern of results. In both experiments there was a main effect for word category (past vs. neutral vs. future). In both experiments, future words induced faster discriminations than past words and with neutral words in between.

In the first and second experiments, we obtained a word category x target location interaction. In the first experiment, this effect was driven by the orthographic left-right convention and in the second by a right-left convention. Our Arabic speaking sample mapped the past on right spatial coordinates. Past-related words facilitated the detection of the target string on the right rather than on the left. The reverse was noted for future-related words. This facilitated detection of the target letter on the left target string rather than on the right. This congruency effect reflects the left-right embodied grounding of the cue words and was precisely the reverse of the pattern obtained in Experiment 1.

More importantly, in both experiments the comparison between the detection latencies observed for the two congruent conditions (exp.1: future word – target right vs. past word –

target left; exp. 2: future word – target left vs. past word – target right) revealed that the discrimination of target letters at their respective locations was modulated, as predicted, by the cultural habits. In experiment 1, future related cue words facilitated detection of the target in the right target string to a greater extent than past related cue words facilitated detection of the target on the left letter string. Experiment 2 revealed precisely the reverse pattern, future related cue words facilitated target detection on the left target string to a greater extent than past related cue words facilitated the detection of the target embedded in the right letter string. This asymmetry effect reflects the left-right and right-left habitual language direction. These findings show that it is not only the semantic indication of the cue words (Ouellet, Santiago, Funes, et al., 2010; Torralbo et al., 2006; Weger & Pratt, 2008) but the culturally driven orthographic direction (Maass & Russo, 2003; Suitner & Maass, 2016) that modulate how discrimination speed is driven. Furthermore, the consistency of this dual influence on how attention is driven in a detection paradigm is shown to be operating in similar ways in both cultures.

In experiment 1, temporal cue words were presented both visually and auditorily. This manipulation did not affect the interaction between word category and target location on response times. Importantly, this reveals that the asymmetry between the congruent pairs emerges irrespective of the modality in which cues are delivered. Further, it confirms that lateralized preferences on the representation of time converge across visual and auditory space (Lakens et al., 2011). Notably, the task comprised both unimodal cueing (cue and target belonging to the same modality; visual trials), and cross-modal cueing (cue and target belonging to different modalities; auditory trials), the first typically producing larger effects than the latter because stimuli processing benefits from the format similarity (Weatherford et al., 2015). Despite that in visual trials participants may have been more prepared to process targets (see Spence & Santangelo, 2009 for a review), visuomotor performance in visual and auditory trials was comparable. This indicates that the presumed interference introduced by cross-modal presentation was insufficient to disrupt the effect of the attention-orienting forces. The visual-auditory convergence also shows that the lateral bias is not a by-product of the directional act of reading, or a ‘reading effect’ (Jainta et al., 2015). Target detection did not benefit from carryover effects of the reading process since auditory words (which do not activate the same motoric processes involved in reading) yielded the same pattern as visual words. This lends credence to our argument that asymmetries in visual attention are fueled by two co-occurring bias: the spatial referent that time words hold (Bender & Beller, 2014) and the complementary directional practices instilled by language/culture (Suitner & Maass, 2016).

Finally, in experiment 1, the examination of the direction of the first saccade showed that it was a response to the spatial referent of the cue word. This confirmed that noninformative cues were successful in producing the expected attention shifts. We should also highlight that word cues were derived from an abstract category and were not mere locatives (e.g., ‘left’, ‘right’) that are highly regular in everyday discourse (Hommel et al., 2001). The first saccade measure was complemented by the time to first fixation that underscored the pattern observed in detection decisions. The imbalance in first fixation onset between congruent conditions favored rightward cue-target configurations coherent with the participants’ LR dominant orthographic system. This meshes well with the body of research reporting the impact of asymmetric reading-writing practices in distinct tasks (Bergen & Chan Lau, 2012; Ouellet, Santiago, Israeli, et al., 2010; Spalek & Hammad, 2005).

Critically, we show that embodied elements of culture motivate lateralized spatial biases. However, abundant research has identified that diverse aspects of linguistic, cultural, and personal experience modulate how people construe time. To provide definite conclusions on the asymmetric performance we claim, future studies ought to address if the phenomenon is affected by personal and cultural modulators (e.g., co-speech gesturing, temporal focus, cognitive availability, age, gender; see Boroditsky, 2011 for a review). It would also be interesting to test if these asymmetries translate into other abstract concepts mapped horizontally, like politics (Farias et al., 2013; Mills et al., 2015), which are a) further removed from the concrete experience of space, and b) less frequent than those of time in everyday discourse. Finally, we were not able to collect gaze movement for the Arabic-speaking population. Although the mirrored detections in the two experiments enable us to infer that Arabic participants would have a symmetric attentional performance to that observed for Portuguese participants, we encourage other researchers to confirm the spatial bias in RL linguistic communities. The same applies to the testing in the auditory modality. In sum, broader evidence is needed to irrevocably establish that asymmetries in visuomotor performance are derived from the added influence of reading direction on embodied groundings.

To conclude, in a cross-cultural set of studies, we demonstrated that two sources of bias, namely the grounding of words and the cultural orthographic habits, operate in conjunction to induce an asymmetric movement direction that constrains detection decisions. Inherently nonspatial words triggered not only spatially consistent responses, but these were further modulated by script direction and convergent across modalities. This research informs researchers about people’s spatial preferences when scanning the surrounding environment.

References

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample-size planning for more accurate statistical power: A method adjusting sample effect sizes for publication bias and uncertainty. *Psychological Science*, *28*(11), 1547–1562. https://doi.org/10.1177/0956797617723724

Anwyl-Irvine, A. L., Massonnié, J., Flitton, A., Kirkham, N., & Evershed, J. K. (2020). Gorilla in our midst: An online behavioral experiment builder. *Behavior Research Methods*, *52*(1), 388–407. https://doi.org/10.3758/s13428-019-01237-x

Bender, A., & Beller, S. (2014). Mapping spatial frames of reference onto time: A review of theoretical accounts and empirical findings. *Cognition*, *132*(3), 342–382. https://doi.org/10.1016/j.cognition.2014.03.016

Bergen, B. K., & Lau, T. T. C. (2012). Writing direction affects how people map space onto time. *Frontiers in Psychology*, *3*(APR), 109. https://doi.org/10.3389/fpsyg.2012.00109

Bettinsoli, M. L., Maass, A., & Suitner, C. (2019). The first, the least and the last: Spatial asymmetries in memory and their relation to script trajectory. *Memory and Cognition*, *47*, 229–239. https://doi.org/10.3758/s13421-018-0861-1

Blom, S. S. A. H., & Semin, G. R. (2013). Moving events in time: Time-referent hand-arm movements influence perceived temporal distance to past events. *Journal of Experimental Psychology: General*, *142*(2), 319–322. https://doi.org/10.1037/a0029026

Boroditsky, L. (2011). How languages construct time. In *Space, Time and Number in the Brain* (pp. 333–341). Elsevier Inc. https://doi.org/10.1016/B978-0-12-385948-8.00020-7

Casasanto, D. (2014). Experiential origins of mental metaphors: Language, culture, and the body. In *The power of metaphor: Examining its influence on social life.* (pp. 249–268). American Psychological Association. https://doi.org/10.1037/14278-011

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition*, *106*(2), 579–593. https://doi.org/10.1016/j.cognition.2007.03.004

Chokron, S., & De Agostini, M. (2000). Reading habits influence aesthetic preference. *Cognitive Brain Research*, *10*(1–2), 45–49. https://doi.org/10.1016/S0926-6410(00)00021-5

Cristescu, T. C., Devlin, J. T., & Nobre, A. C. (2006). Orienting attention to semantic categories. *NeuroImage*, *33*(4), 1178–1187.

https://doi.org/10.1016/j.neuroimage.2006.08.017

Farias, A. R., Garrido, M. V., & Semin, G. R. (2013). Converging modalities ground abstract categories: The case of politics. *PLoS ONE*, *8*(4), e60971. https://doi.org/10.1371/journal.pone.0060971

Fuhrman, O., & Boroditsky, L. (2010). Cross-cultural differences in mental representations of time: Evidence from an implicit nonlinguistic task. *Cognitive Science*, *34*(8), 1430–1451. https://doi.org/10.1111/j.1551-6709.2010.01105.x

Ho, C., & Spence, C. (2005). Assessing the effectiveness of various auditory cues in capturing a driver’s visual attention. *Journal of Experimental Psychology: Applied*, *11*(3), 157–174. https://doi.org/10.1037/1076-898X.11.3.157

Hommel, B., Pratt, J., Colzato, L., & Godijn, R. (2001). Symbolic control of visual attention. *Psychological Science*, *12*(5), 360–365. https://doi.org/10.1111/1467-9280.00367

Jainta, S., Blythe, H. I., Nikolova, M., Jones, M. O., & Liversedge, S. P. (2015). A comparative analysis of vertical and horizontal fixation disparity in sentence reading. *Vision Research*, *110*(Part A), 118–127. https://doi.org/10.1016/j.visres.2015.03.008

Lakens, D., Semin, G. R., & Garrido, M. V. (2011). The sound of time: Cross-modal convergence in the spatial structuring of time. *Consciousness and Cognition*, *20*(2), 437–443. https://doi.org/10.1016/j.concog.2010.09.020

Maass, A., Pagani, D., & Berta, E. (2007). How beautiful is the goal and how violent is the fistfight? Spatial bias in the interpretation of human behavior. *Social Cognition*, *25*(6), 833–852. https://doi.org/10.1521/soco.2007.25.6.833

Maass, A., & Russo, A. (2003). Directional bias in the mental representation of spatial events: Nature or culture? *Psychological Science*, *14*(4), 296–301. https://doi.org/10.1111/1467-9280.14421

Mendonça, R, Garrido, M. V, & Semin, G. R. (2020). Social inferences from faces as a function of the left-to-right movement continuum. *Frontiers in Psychology*, *11*, 1488. https://doi.org/10.3389/fpsyg.2020.01488

Mendonça, Rita, Garrido, M. V, & Semin, G. R. (2020). Asymmetric practices of reading and writing shape visuospatial attention and discrimination. *Scientific Reports*, *10*(1), 21100. https://doi.org/10.1038/s41598-020-78080-0

Mills, M., Smith, K. B., Hibbing, J. R., & Dodd, M. D. (2015). Obama cares about visuo-spatial attention: Perception of political figures moves attention and determines gaze direction. *Behavioural Brain Research*, *278*, 221–225. https://doi.org/10.1016/j.bbr.2014.09.048

Ouellet, M., Santiago, J., Funes, M. J., & Lupiáñez, J. (2010). Thinking about the future moves attention to the right. *Journal of Experimental Psychology: Human Perception and Performance*, *36*(1), 17–24. https://doi.org/10.1037/a0017176

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (2010). Is the future the right time? *Experimental Psychology*, *57*(4), 308–314. https://doi.org/10.1027/1618-3169/a000036

Rinaldi, L., Di Luca, S., Henik, A., & Girelli, L. (2014). Reading direction shifts visuospatial attention: An Interactive Account of attentional biases. *Acta Psychologica*, *151*, 98–105. https://doi.org/10.1016/j.actpsy.2014.05.018

Román, A., Flumini, A., Lizano, P., Escobar, M., & Santiago, J. (2015). Reading direction causes spatial biases in mental model construction in language understanding. *Scientific Reports*, *5*, 18248. https://doi.org/10.1038/srep18248

Santiago, J., Lupiáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin and Review*, *14*, 512–516. https://doi.org/10.3758/BF03194099

Spalek, T. M., & Hammad, S. (2005). The left-to-right bias in inhibition of return is due to the direction of reading. *Psychological Science*, *16*(1), 15–18. https://doi.org/10.1111/j.0956-7976.2005.00774.x

Spence, C., & Santangelo, V. (2009). Capturing spatial attention with multisensory cues: A review. *Hearing Research*, *258*(1–2), 134–142. https://doi.org/10.1016/j.heares.2009.04.015

Suitner, C., & Maass, A. (2016). Spatial agency bias: Representing people in space. *Advances in Experimental Social Psychology*, *53*, 245–301. https://doi.org/10.1016/bs.aesp.2015.09.004

Torralbo, A., Santiago, J., & Lupiáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science*, *30*(4), 745–757. https://doi.org/10.1207/s15516709cog0000_67

von Sobbe, L., Scheifele, E., Maienborn, C., & Ulrich, R. (2019). The space-time congruency effect: A meta-analysis. *Cognitive Science*, *43*(1), e12709. https://doi.org/10.1111/cogs.12709

Weatherford, K., Mills, M., Porter, A. M., & Goolkasian, P. (2015). Target categorization with primes that vary in both congruency and sense modality. *Frontiers in Psychology*, *6*, 20. https://doi.org/10.3389/fpsyg.2015.00020

Weger, U. W., & Pratt, J. (2008). Time flies like an arrow: Space-time compatibility effects suggest the use of a mental timeline. *Psychonomic Bulletin and Review*, *15*(2), 426–430. https://doi.org/10.3758/PBR.15.2.426

Appendix 1. Experimental materials from Experiment 1.

Past	***Neutral***	***Future***
Passado	*Hora*	*Futuro*
(past)	(hour)	(future)
Ontem	*Minuto*	*Amanhã*
(yesterday)	(minute)	(tomorrow)
Anteriormente	*Milénio*	*Posteriormente*
(previously)	(millennium)	(subsequently)
Antes	*Sazonal*	*Depois*
(before)	(seasonal)	(after)
Antigamente	*Contemporâneo*	*De seguida*
(formerly)	(contemporary)	(next)
Recentemente	*Diário*	*Depois de amanhã*
(recently)	(daily)	*(*after tomorrow)
Anteontem	*Semana*	*Em breve*
(before yesterday)	(week)	(soon)
Há pouco tempo	*Mês*	*Imediatamente*
(not long ago)	(month)	(immediately)
Apareceu	*Trimestre*	*Aparecerá*
(he showed up)	(quarter)	(he will show up)
Procurou	*Quinzena*	*Procurará*
(he looked for)	(fortnight)	(he will look for)
Conduziram	*Duração*	*Conduzirão*
(they drove)	(duration)	(they will drive)
Decidiram	*Hoje*	*Decidirão*
(they decided)	(today)	(they will decide)
Disse	*Momento*	*Dirá*
(he said)	(moment)	(he will say)
Foi	*Temporada*	*Irá*
(he went)	(season)	(he will go)
Fizeram	*Data*	*Farão*
(they did)	(date)	(they will do)
Viram	*Dia*	*Dirão*
(they saw)	(day)	(they will say)

Appendix 2. Sample characterization

At the end of the experiment, we collected additional information to characterize our sample better. Participants' mother-tongue was Arabic, and they were nationals of the following Arabic-speaking countries: Iraq (1), Egypt (8), Jordan (5), Lebanon (4), Libya (1), Morocco (9), Palestine (4), Qatar (2), Saudi Arabia (2), Syria (5), Tunisia (8), and UAE (1). The majority of the participants (82%) had university degrees, and the remaining had attended high school. All participants except one reported speaking one additional language. These were English (73.47%), French (14.29%), Spanish (6.12%), German (4.08%), and Turkish (2.04%). Forty-seven participants reported having lived abroad in the following countries: Belgium (1), Brazil (1), Canada (3), Czech Republic (1), Denmark (1), Estonia (1), France (10), Germany (6), Greece (1), Hungary (2), Italy (1), Jordan (2), Latvia (1), Malaysia (1), Mexico (1), Portugal (1), Saudi Arabia (1), Spain (1), Sweden (2), Turkey (1), UK (7), USA (1). The minimum period spent abroad was one year, and a maximum of 15 years. To the question "Do you use social media (Facebook, Twitter, Instagram) in Arabic?", 84% of participants said yes. To the question "Do you watch movies/tv-shows/read books in Arabic?", 60% of participants said yes. To the question "Do you read news (news websites, newspapers) in Arabic?", 54% of participants said yes. Finally, 84% of the participants said yes to the question, "Do you have family conversations in Arabic in your everyday life?". When asked to move a slider on a horizontal line to indicate "How much contact in everyday life do you have with your native language - Arabic?"; the average response was 58.54%, and "How much contact in everyday life do you have with languages that are written from left-to-right (e.g., English, French, …)?"; the average response was 47.7%.

Appendix 3. Experimental materials from Experiment 2.

Past	***Neutral***	***Future***
ماضي (past)	ساعة (hour)	مستقبل (future)
أمس (yesterday)	دقيقة (minute)	غداً (tomorrow)
سابقاً (previously)	ألفيّة (millennium)	لاحقاً (subsequently)
قبل (before)	موسمي (seasonal)	بعد (after)
فيما مضى (formerly)	معاصر (contemporary)	تالي (next)
مؤخراً (recently)	يومي (daily)	بعد غدٍ (after tomorrow)
قبل أمس (before yesterday)	اسبوع (week)	قريباً (soon)
ليس من مدة طويلة (not long ago)	شهر (month)	حالاً (immediately)
ظهرَ (he showed up)	ربع سنة (quarter)	سيظهر (he will show up)
بحثَ عن (he looked for)	اسبوعان (fortnight)	سيبحث عن (he will look for)
قادوا (they drove)	مدّة (duration)	سيقودون (they will drive)
قرروا (they decided)	اليوم (today)	سيقررون (they will decide)
قالَ (he said)	لحظة (moment)	سيقول (he will say)
ذهبَ (he went)	موسم (season)	سيذهب (he will go)
فعلوا (they did)	تاريخ (date)	سيفعلون (they will do)
رأوا (they saw)	يوم (day)	سيقولون (they will say)

Chapter V.

Reading and writing direction biases visuospatial attention: The case for politics

Chapter based on:

Mendonça, R., Garrido, M. V., & Semin, G. R. (in preparation). Reading and writing direction biases visuospatial attention: The case for politics.

Abstract

In one experiment we investigate if directional scanning practices derived from activities of reading and writing constrain attention and detection to the left and right hemifields. Politically-related words, known to ground horizontally in space (left-socialism; right-conservatism), were used as cue stimuli presented visually and auditorily in a spatial cueing task. Both manual and gaze measures were recorded. Results show that attention is not evenly distributed across space but follows a trajectory consistent with the culturally maintained script direction. An asymmetric performance in response time revealed that detection was faster following conservatism-related words and targets on the right space, relative to socialism-related words and targets on the left space. The first saccadic movement was consistent with the ideology of the word cue, attesting that political categories induce congruent attention shifts. The time to first fixation complemented behavioral results by revealing that participants looked at the right area of interest earlier in the trial after being exposed to a conservatism-related word as compared to when they looked at the left area of interest after a socialism-related word. The results were not differentiated across modalities which indicates that the instances of the political concepts are convergent in visual and auditory space. We conclude that participants prioritized words with a political referent that is rightward anchored, alike their habitualized scanning routines. This privileged processing instilled by culture gave rise to biased attention shifts and detection latencies.

Keywords

Spatial bias; Politics; Language Script; Abstract Concepts; Eye-Tracking.

Introduction

Embodied accounts of information processing suggest that the representation of concepts is linked to their experiential origins that are embodied and later activated when concepts are processed (Barsalou, 2008; Glenberg & Gallese, 2012; Zwaan, 2004). They argue that cognitive functioning resides in the interaction between perception and action systems. This view has was advanced to contrast with amodal theories that contend that symbolic representation is fundamentally non-perceptual and cognition is an invariant information processing system (Fodor, 1975; Landauer & Dumais, 1997).

Evidence that supports embodied cognition theory is documented by research that can be seen as consisting of four main categories. The first concerns the connection between linguistic and motor systems in reasoning. For example, people perform faster when there is a match between the direction of their arm movement (push/pull) and the implied direction of action sentences using both concrete and abstract entities (Glenberg & Kaschak, 2002). Likewise, inconsistent arrangements between response movements (e.g., looking up/down) and the concepts' implied direction impair gaze and reaction time responses (Estes et al., 2008; Meteyard et al., 2007). Second, there is research demonstrating that multiple sensory modalities are involved when people reason about abstractions. Lakens and colleagues (2011) have shown that the mental representation of time shares a cross-modal structure across vision and audition. The engagement of sensory-motor simulations is required for the comprehension of abstract and concrete language alike (Boroditsky & Ramscar, 2002; Richardson et al., 2003; Sell & Kaschak, 2012). Third, evidence from conceptual metaphor theory (Lakoff & Johnson, 1980) holds that concepts lacking sensorial experience are understood metaphorically through concrete referents in the environment. There is compelling evidence that language processing relies on embodied metaphorical representations that activate motor, visual, and emotional information (Foroni & Semin, 2009; Kaschak & Borreggine, 2008; Knoblich & Flach, 2001) and that the same brain regions are triggered when people process words and their spatial referents (Gallese, 2008; Kan et al., 2003). For example, morality is comprehended in terms of color (Sherman & Clore, 2009), importance in terms of weight (Jostmann et al., 2009), gender in terms of brightness (Semin & Palma, 2014), social closeness in terms of temperature and proximity (Ijzerman & Semin, 2009), power and affect in terms of verticality (Meier & Robinson, 2004a; Schubert, 2005), timeline (Santiago et al., 2007), number-line (Dehaene et al., 1993), and political attitudes (Farias et al., 2013) in terms of a horizontal spatial continuum. These studies demonstrated that mental metaphors ground basic processes of learning, memory, attention, and judgment.

Finally, a more recent research trend has shown that culture shapes the metaphorical representation of concepts devoid of physical grounding by enforcing subtle directional preferences. These include, among others, the dominant script direction in a given culture, co-speech gesturing, and other cultural artifacts like pictorial representations that mark spatial regularities (e.g., graphs, calendars, billboards) (Casasanto & Jasmin, 2012; Román et al., 2015; Suitner & Maass, 2016). Specifically, the sensory-motor iterations that result from the left-right manual and ocular movements performed in reading-writing weigh on how people come to conceptualize human agency (Maass et al., 2007; Maass & Russo, 2003; Suitner & Maass, 2016) and generalize to other abstract concepts. Therefore, all abstract concepts that rely on the tangible horizontal dimension to be grasped become permeable to these habitualized directional scanning practices evolving linearly in space. In the domain of time, research has shown that left-to-right language scripts lead to the mapping of visual past words on the left (i.e. where writing starts) and future words on the right (i.e. where writing ends) (Ouellet, Santiago, Funes, et al., 2010; Weger & Pratt, 2008). This spatial schema is equally manifested auditorily (Lakens et al., 2011) and reverses with participants from right-to-left scripts (Fuhrman & Boroditsky, 2010; Ouellet, Santiago, Israeli, et al., 2010). In 'Western' populations, numerical magnitude is understood through small numbers to the left of large numbers (Dehaene et al., 1993), and is spatialized under directional scanning habits (Shaki et al., 2009). However, while time and number are extensively studied domains in conceptual metaphor literature, politics are not. Although there is evidence that political positions are spatially coded (Farias et al., 2013, 2016), no study to date has examined whether the mapping of politics in space is biased by the direction of reading and writing movement.

People often use spatial terms to symbolize and communicate the political landscape. In particular, the political ideology of individuals or governments is typically articulated in terms of spatial coordinates of 'left' (socialist/liberal approaches), 'center' (moderate approaches), or 'right' (conservative/traditionalist approaches). The left/right divide can be traced back to the 18th century Estates-General assembly in France. It is said to have originated from the arbitrary seating arrangements of those in support of the King's policies to the right, and those against them to the left. Not long after had these labels gained currency and entered everyday conversation. To date, the terms 'left' and 'right' (and its derivatives, e.g., 'soft-left', 'soft-right') are still fervently used in political debate to describe opposite ends of the political spectrum, despite the spatial elements of seating practices have long been discontinued (Goodsell, 1988). It is therefore puzzling that the left/right metaphor prevails in present-day political semantics when physical spatial associations no longer exist. Chronic exposure to this metaphor (like to others mentioned above) is likely to forge enduring semantic associations between socialism/conservatism and left/right space, respectively.

There is limited but consistent research regarding the activation of spatial information following the processing of political categories. In line with embodied and situated approaches, Oppenheimer and Trail (2010) observed that reported political attitudes shifted slightly by physically orienting participants towards the left or right. Likewise, additional evidence that political metaphors are grounded in space comes from a study showing that implicit posture manipulation (leaning to a side) via Wii Balance Board influences political party evaluations (Dijkstra et al., 2012). Other work demonstrated that political acronyms induce faster button press when political party ideology and hand for responding coincide (van Elk et al., 2010). Similarly, responses are facilitated when the acronym is presented on the side of the screen (left/right) that matches its political stance. These studies, it should be noted, are not above explanations based on stimulus-response compatibility effect (Fitts & Seeger, 1953). The processing of political metaphor has further consequences for the orientation of attention. For instance, the representation of political ideology was found to induce attention shifts following pictures of left (right) politicians and to bias gaze direction in line with the politicians' ideology (Mills et al., 2015). As for linguistic primes, Farias and colleagues (2013) showed that when asked to place political terms on a horizontal line, participants display a lateralized bias by placing socialism-referent words more to the left, and conservatism-referent words more to the right. When these words are presented auditorily and equally loudly on both channels, conservatism-referent words are judged to be louder on the right ear and socialism-referent words on the left ear (Farias et al., 2016). This research indicates that, similarly to language comprehension about time (Casasanto & Boroditsky, 2008; Santiago et al., 2010), political categories are transmitted by metaphorical language, and trigger a spatial schema that is susceptible to cultural determinants. The fact that political spatial language is fairly recent and arguably less entrenched than terms derived from other abstract categories, has perhaps discouraged researchers to explore this abstract concept further. However, because politics are less associated with space than, for example, time (assuming that political spatial metaphor arises from incidental historical events and not sensory-motor basis), it becomes particularly relevant to test if the abstract category of politics can also affect spatial performance and be biased by directional scanning habits imposed by script.

Overview

The research we report builds upon the asymmetrical visuomotor performance demonstrated in chapter III with face cues, and in chapter IV with time-related word cues. The rationale was to extend evidence regarding the bias that reading-writing practices exert on attention and detection to the unexamined domain of politics which is also tied to space. Previous studies confirmed that political categories induce a semantic bias in line with their underlying connotation (Farias et al., 2013, 2016) but research has not yet settled whether political spatial mappings are modulated by the left-right trajectory of language direction. In a spatial cueing task, we used politically laden words (socialism vs. neutral vs. conservatism) as attention orienting primes to targets embedded in left and right space. We expected a differentiation between congruent conditions, in that cue-target pairs with a right spatial referent (conservatism-related words and targets on the right hemifield) would facilitate both motor and gaze performance relative to left-cue left-target pairs. This is because cue-target combinations about the right are aligned with the participants' culturally ascribed left-to-right trajectory of language script. Newly, and to ascertain whether sensory modalities are involved in the comprehension of abstract information, the visuomotor asymmetry account was examined by delivering cue words visually and auditorily.

The predictions were: 1) Overall, detection facilitation for congruent (versus incongruent) cue-target conditions, that is, shorter response times when political cue word connotation is consistent with the target letter location; 2) The specific effects predicted under 1), to be asymmetric between congruent cue-target pairs. In other words, the rightward influence should manifest itself in the case of conservatism-related cue words when the target location is on the right hemifield relative to the response times of congruent socialism-related words and target letter on the left hemifield; 3) Initial gaze movement should respond to the political meaning of the word primes; 4) Time to first fixation in the area of interest (AOI) to be shorter for congruent compared to incongruent conditions, but revealing the asymmetric advantage for conservatism cues and right AOI relative to socialism cue - left AOI pairings; 5) Neutral political words to reflect intermediate values but resembling both manual response and gaze performance outcomes for socialism-related words. Neutral words, as a baseline condition, should not prime any directionality and hence induce the habitualized left-to-right visual exploration; 6) Visual and auditory modalities should render similar effects, although smaller ones in the latter case.

Method

Participants

Forty-three undergraduate students were recruited (30 females, $M_{age} = 21.06$, $SD = 2.44$; nine self-reported left-handers). Sample size was determined a priori using BUCSS R method (Anderson et al., 2017, desirable level of assurance = .90; statistical power = .80) as in earlier studies (Farias et al., 2013). Participants were screened for normal or corrected-to-normal visual acuity and reported no hearing problems. They were self-declared native speakers of Portuguese and had not spent any significant time in countries with right-to-left language scripts. All participants gave written informed consent for their participation. The experiment was performed according to the Declaration of Helsinki and approved by the Ethics Committee of ISPA – Instituto Universitário.

Cues

48 words were selected from a list of political words in Portuguese (Garrido et al., 2010) that had been used in earlier studies (Farias et al., 2013). The selection consisted of 16 words with a politically left-view connotation (socialism-related, e.g. “sindicato” – “union”) and 16 with a politically right-view connotation (conservatism-related, e.g. “capitalismo” – “capitalism”). Additionally, there were 16 politically neutral words (e.g., “leis” – “laws”) (see Appendix 1 for the entire list). We pre-tested the list of words with a Portuguese sample (n = 102) by asking participants to indicate the scale point best representing the political ideology of the word (1 = *politically-left oriented*, 7 = *politically-right oriented*). The words were grouped based on their mean ratings and tested for their semantic meaning, which was significantly different, F (2, 47) = 484.75, p < .001, (Socialism: M = 2.53, SD = .32; Neutral: M = 4.00, SD = .08; Conservatism: M = 5.06, SD = .23; *p’s* < .001 between groups). The politically loaded words were overall neutral in valence to dismiss confounds between valence and the horizontal dimension (Casasanto, 2009). Eight additional politically neutral words served as cues in the warm-up trials. Visual words were centrally presented on the screen and the maximum word length subtended 6.68° visual angle (± 3.34° eccentricity). Words were then converted to sound files using a text-to-speech application. Word duration did not differ across political orientation, F (2, 47) = .275, p = .761 (M = 1172.43, SD = 185.05). Throughout the experiment, each word was presented twice visually and twice auditorily.

Targets

Target stimuli consisted of two sets of five letters. Only one set contained one of the two possible target letters – *q* or *p*. The remaining letters on the set were distractors. The letter strings subtended 4.77° visual angle and were simultaneously presented in the near peripheral visual field at the left and right sides of the screen midpoint (±13.31° eccentricity). This means that it was not possible to process the target letter strings without performing eye movements. Distractor and target letters were kept constant across the experiment and were presented randomly over trials within the five possible letter positions. Because the task was to discriminate between two target letters and not merely detect a target nor its location, this setup avoided the dimensional overlap between effector and target location.

Apparatus and Display

The task was programmed in Experiment Builder (Version 1.10.1630, SR Research, 2016). The stimuli were displayed on an Asus VX238H 23" Full HD LED monitor (1920x1080) driven by a Dell OptiPlex 755 with a refresh rate of 60 Hz. Participants' eye movements were calibrated and recorded from their dominant eye (viewing was binocular) with a 1000 Hz Eyelink 1000 plus. Calibration was performed with the five-point calibration procedure, resulting in a reported interval of 0.25° - 0.5° average accuracy for all points. Errors higher than 1° at any point led to a repetition in the calibration procedure. A chin rest restricted participants' head movements and controlled the viewing distance to 60 cm. The task was presented against a medium gray background. Manual responses were collected using the keys marked as *q* and *p* on a standard gamepad. Auditory stimuli were presented via Sony headphones.

Procedure

Participants sat in front of the screen with headphones on and read the instructions. They were instructed to press the respective response key on the gamepad as soon as they detected the target letter embedded in one of the two letter strings. They were also informed that the words, either visual or auditory, were task-irrelevant. The task was a variation of the spatial cueing paradigm. Each trial began with a 1000 ms drift check fixation (0.3° × 0.3°) which was gaze contingent therefore anchoring the initial gaze movement of the participants at the center of the screen. The drift check was followed by the presentation of the word cue, either visually at the center of the screen for 1000 ms or auditorily via headphones for the duration of the sound file. Auditory stimuli were presented binaurally and equally loud to both auditory channels. During the auditory stimuli presentation, a gaze-contingent cross was presented in the center of the blank screen, ensuring participants' starting point of visual exploration at target onset. A blank screen followed the cue and lasted 150 ms. The two letter strings were then simultaneously presented to the left and right sides of the screen until participants responded or if 1000 ms had elapsed. After responding, participants were informed about the accuracy of their response on a feedback screen. There were 192 trials in total, divided into 2 blocks, plus 16 practice trials. Participants took a 5-minute break between blocks followed by a recalibration. The experiment took approximately 30 minutes to complete.

Results

Reaction Time

Response times under 100 ms were considered anticipatory responses and were excluded from the analysis (1.1%). Missing responses (trials where the time for responding elapsed) corresponded to roughly 23% of the total number of trials across participants.

To address our prediction for facilitated detection in trials where cue and target are spatially congruent (H1) and for an asymmetry in performance favoring rightward cue-target pairs (H2), we performed a linear mixed model analysis (LMM). The LMM included word ID, word length, and participant ID as clustering variables, prime modality (visual vs. auditory), word category (socialism-related vs. neutral vs. conservatism-related), and target location (left vs. right) as categorical independent factors and response time as the dependent variable. The model's fixed effects were prime modality, word category, target location, and their second- and third-order interactions. Random intercepts per participant, word ID, and word length were included. Word length observed a variance of 0 and was removed from the model. The model was estimated using restricted maximum likelihood with a Satterthwaite approximation of the degrees of freedom, and performed in jamovi software (version 1.2) with the GAMLj module.

The LMM analysis ($R^2_{marginal} = .02$; $R^2_{conditional} = .10$) revealed a main effect of prime modality, F (1, 4698.2) = 15.435, $p < .001$, that showed faster reaction time for visual words (M = 686, SE = 6.84) than auditory words (M = 702, SE = 6.81; $p < .001$). Word category was also marginally significant, F (2, 40.7) = 3.218, p = .05. Post-hoc comparisons with Holm correction did not reveal significant differences across the political connotation of words (p's > .08). However, an inspection to the fixed effects parameter estimates for the comparison between conservatism (M = 689, SE = 7.22) and socialism words (M = 702, SE = 7.21) indicates that the first are significantly more likely to induce shorter response latencies than the latter, β = -12.03, SE = 5.29, t (40.4) = -2.273, p = .03. Importantly, we report a significant interaction between word category and target location, F (2, 40.7) = 6.704, p = .003 (Figure 1). As predicted, conservatism-related words generated faster responses to the right target (M = 671, SE = 8.13; $p < .001$) than to the left (M = 708, SE = 8.17). However, we failed to observe this same congruency effect regarding the left space, that is, socialism-related words gave rise to similar detection of targets on the left (M = 701, SE = 8.14) and right (M = 702, SE = 8.11; p > .250). Likewise, detection for targets on the left (M = 695, SE = 8.14) and right space (M = 686, SE = 8.15; p > .250) were the same following politically neutral words. The third-order interaction was not significant (p = .159).

Finally, we tested H2 where we predicted an asymmetry in response time, specifically a right-sided facilitation for target detection following conservatism-related words. To this end, we compared the effects between socialism words and target on the left and conservatism words and target on the right. Because the third-order main effect was not significant, this difference was tested irrespective of prime modality. We observed a clear imbalance in response time favoring rightward cue-target relative to leftward cue-target pairs, t (40.7) = 4.0245, p = .003.

To exclude handedness as accountable for the observed cueing effects, we examined average response times that occurred when participants used the *q* key (M = 696.19, SE = 58.28; pressed with the left index finger) and the *p* key (M = 688.40, SE = 57.54; pressed with the right index finger). There was no facilitation in response latencies due to responding with the left or right hand, t (52) = 1.281, p = .206.

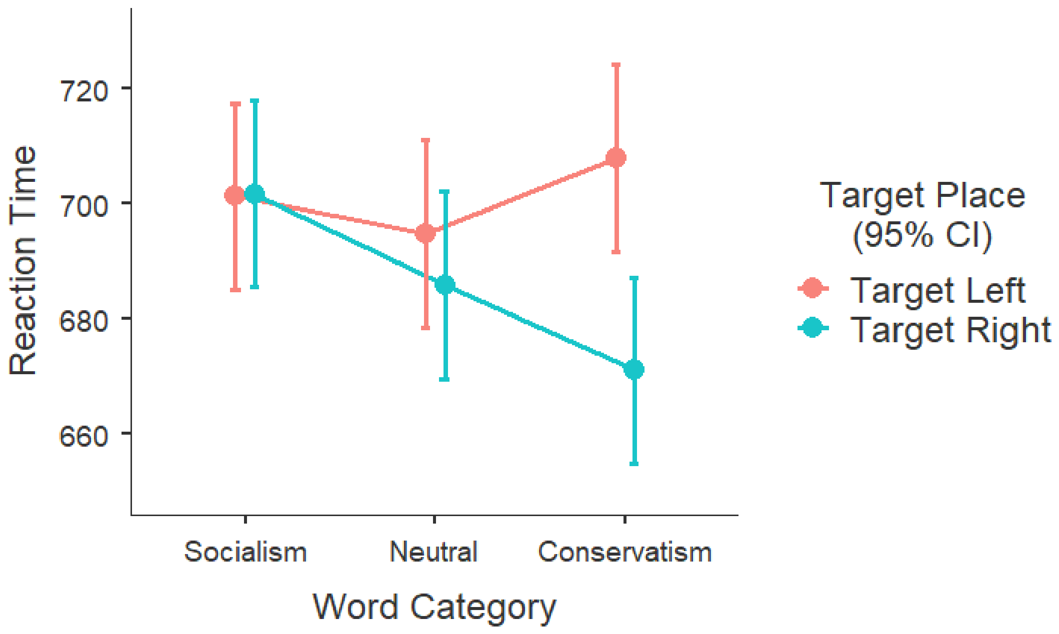

Figure 1. Mean reaction time (in milliseconds) as a function of the word category and the target letter location. Error bars represent 95% confidence intervals.

Eye Tracking Data

Trials in which the observer's gaze at fixation could not be verified to be within 1° of visual angle or for a minimum of 1000 ms were excluded (0.8% across all trials fixations). Fixations under 80 ms were excluded (0.9%) as were trials in which the tracker lost eye position (1.4%). We defined two rectangular areas of interest (AOI) which correspond to the target letter strings located on the left and right sides of the screen. Eye gaze measures were recorded from target onset.

Direction of the First Saccade

Because the direction of the first saccade was a binary variable (left/right), it was analyzed in a logistic mixed-effects model. The model predicted the probability of the direction of the first saccade (0 = saccade to the left; 1 = saccade to the right). Prime modality (visual vs. auditory) and word category (past vs. neutral vs. future) and their interaction were entered as fixed effects. Target letter location was not included as a factor in this analysis because, as hypothesized (H3), we were interested in testing the first, automatic response to the prime and confirming whether the political words served as attention-orienting primes. Intercepts for word ID and participant ID were included as random effects. Data from one participant was not included due to a software problem during the recording session (n = 52).

The model ($R^2_{marginal}$ = .02; $R^2_{conditional}$ = .20) confirmed that attention was not distributed at will over the visual field but in a spatially-specific manner. The political connotation of the words influenced the direction of the first saccade, χ^2 = 116.4961, df = 2, p < .001. Taking the socialism-related words as the reference category, we observed a positive regression slope for conservatism-related words, which suggests that these words are more likely to trigger saccades to the right space, β = .61, SE = .06, z = 10.646, p < .001. Neutral words were also more likely to induce rightward saccades than the reference category (socialism words), β = .22, SE = .06, z = 3.783, p < .001. Moreover, by attending to the odds ratio, we can conclude that conservatism (vs. socialism) words increased the likelihood of participants initially gazing towards the right by a factor of 1.8 (*CI* [1.649, 2.066]). A further interaction effect between prime modality and word orientation, χ^2 = 16.4588, df = 2, p < .001, revealed a significant negative regression slope for the comparison between auditory and visual primes and conservatism- and socialism-related words, β = -.44, SE = .11, z = -4.040, p < .001. These results indicated that visual cues have an advantage over auditory cues in triggering rightward initial saccades after conservatism than socialism words. The detailed parameter estimates can be found in Table 1.

Table 1. Fixed effects parameter estimates for the logistic mixed model predicting the proportion of the direction of first saccade by prime modality and word category. *** p < .001

				95% CI		
	Effect	**B**	**exp(B)**	**Lower**	**Upper**	***z***
Prime Modality	Auditory – Visual	.00940	.962	.887	1.042	-.9510
Word Category	Neutral – Socialism	.21617***	1.056	.957	1.166	1.0825
Word Category	Conservatism - Socialism	.61276***	1.807	1.636	1.997	11.6531

Prime Modality x Word Category	Auditory – Visual x Neutral – Socialism	-.18354	.894	.734	1.089	-1.1139
Prime Modality x Word Category	Auditory – Visual x Conservatism - Socialism	-.43777***	.669	.548	.815	-.3.9753

Note: Socialism is the reference category for the word category variable.

The post hoc comparisons with Holm correction confirmed that socialism-related words have a lower probability (.44) of generating initial saccades to the right than future words (.60; z = -10.65, p < .001). Likewise, neutral words (.49) are significantly less likely to trigger rightward initial saccades than conservatism words (z = -6.92, p < .001) but more likely than socialism words (z = -3.78, p < .001). As for the significant interaction, auditory socialism words (.46) were less likely to evoke right saccades than auditory conservatism words (.56; z = -5.006, p < .001) just like auditory socialism words (.41) were less likely to trigger right saccades than visual conservatism words (.62; z = -10.473, p < .001). These findings confirm that, in both modalities, socialism and conservatism words primed automatic attention shifts towards their implied direction (H3).

First Fixation Onset

Having established that political terms induce the expected orientation of attention, we investigated if attention was rightward biased. We tested if the time in the trial the first fixation took to land on the left and right areas of interest (AOI) was biased across modalities by rightward word stimuli (H4). Target location was not included because we aimed to show that the initial gaze movement and resulting first fixation was preferentially biased towards the right region of interest, irrespective of whether the target was present or not. Due to a software error during the recording session, data from two participants are not reported in this analysis (n = 51). A LMM analysis was conducted. The model included word ID and participant ID as clustering variables, prime modality (visual vs. auditory), word category (socialism-related vs. neutral vs. conservatism-related), and AOI (left vs. right) as categorical independent factors, and first fixation onset as the dependent variable. The model's fixed effects were prime modality, word category, and AOI, and their second- and third-order interactions. Random effects per participant and word ID were included to control for the variance these factors might introduce in first fixation onset measures. The model was estimated using restricted maximum likelihood, with a Satterthwaite approximation of the degrees of freedom.

Results from the LMM analysis ($R^2_{marginal}$ = .01; $R^2_{conditional}$ = .20) converge with the previous manual responses by showing a main effect of word category, F (2, 9037) = 30.6203, p < .001. Words with conservatism connotation produced earlier first fixations (M = 196, SE = 3.80) than neutral (M = 211, SE = 3.80; p < .001) and past-relevant words (M = 212, SE = 3.80; p < .001). In line with what was previously observed, neutral words did not give rise to different first fixation onsets than socialism words (p > .250). An interaction between word category and AOI emerged, F (2, 9043) = 36.4425, p < .001. As predicted, first fixations landed earlier on the AOI that was congruent with the orientation induced by the political word (Figure 2). This means that participants' first fixation was launched earlier in the trial to the left AOI after a socialism-related word was presented (M = 204, SE = 4.16) than to the right AOI (M = 220, SE = 4.20, p < .001). Likewise, first fixations after words with a right referent, that is, conservatism-related, reached the AOI located on the right earlier (M = 187, SE = 4.19) than on the left AOI (M = 207, SE = 4.19; p < .001). Time taken to first fixation after neutral words was similar in the left (M = 207, SE = 4.18) and right AOI's (M = 215, SE = 4.20; p > .250), suggesting that these words do not strongly induce any directionality (H5). The remaining interactions were not significant (p's > .07). We conclude that first fixations following political words reached their congruently located AOI's faster and this effect was not differentiated between visual and auditory presentation (H6).

To address the proposed rightward asymmetry, a direct comparison between first fixation onset on the left AOI following socialism-oriented words and on the right AOI following conservatism-oriented words, t (9075) = 5.6692, p < .001, confirmed that attention orientation benefits from rightward (vs. leftward) word stimuli, which overlap with the left-to-right scanning practices of the participants.

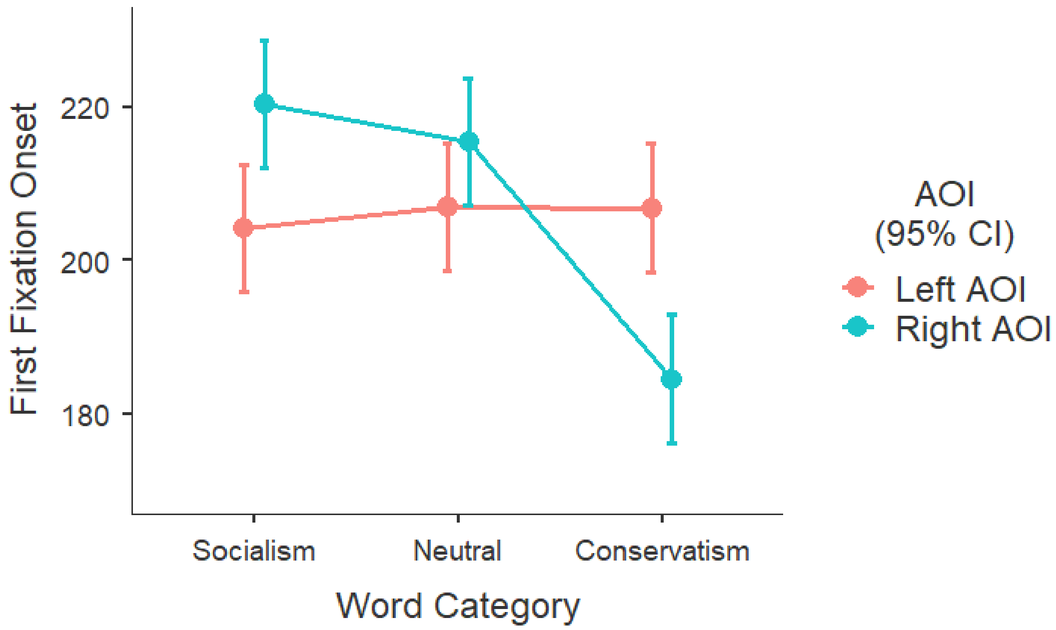

Figure 2. Mean time to first fixation (in milliseconds) as a function of word category and AOI. Error bars represent 95% confidence intervals.

Discussion

This study confirms that people make use of opposites of left-right to structure political ideology in visual and auditory modalities. Moreover, we find that this spatial schema is culturally shaped by a feature of language - script direction. Abstract conceptual words with rightward connotation (that overlaps with participants' reading-writing practices) preferentially captured attention over leftward words, generating an asymmetric motor and gaze performance on the congruent side of space.

First, we show that classic cueing effects (Posner, 1980) are also obtained with words that are relevant to politics in an implicit attention-prompting task. Like it has been shown before with words deriving from other abstract concepts (Lakens et al., 2011), political words have proven efficient in guiding attention. We should note that response time measures failed to reveal the expected congruency effect on the left, as socialism-charged words produced similar latencies on the left and right sides of space. However, gaze movement measures tell us otherwise. The direction of the first saccade responded to socialism words such that attention was oriented leftwards to a greater extent. Consequently, the resulting first fixation was shorter on the left hemifield whenever participants were primed with socialism words. This evidence is derived from an implicit measure of attention (eye tracker) and confirms that words with socialism connotation successfully acted as attention orienting primes, a conclusion that could not be drawn from the reaction time measure alone. Although the time lag between leftward eye movement and detection of the target on the cued side (left) over the non-cued side (right) was not statistically significant to manifest a differentiation, we can positively conclude that attention was captured by 'left' words. On the other hand, the orientation of attention and manual performance for 'right' words was clear-cut. Our results are in line with previous demonstrations of the spatial grounding of politics that have shown that images of well-known politicians (e.g., Barack Obama) bias choice of gaze direction consistent with the political ideology of the figure (left space) (Mills et al., 2015). They advance prior reports by indicating that not only images but inherently non-spatial stimuli – words – can influence free-choice of response in a manner that is script-consistent. Furthermore, they contribute to the substantial body of literature on (other) abstract concepts revealing attentional benefits on spatial locations consistent with the concepts' grounding (e.g., divinity, Meier & Robinson, 2004b; number, Ruiz Fernández et al., 2011; power, Schubert, 2005).

Aside from the contribution to the embodied grounding literature, the added value of this research is to be seen in the asymmetric manual and gaze performance political words induced between left and right hemifields. Conservatism-derived terms systematically favored right detections to a greater extent than socialism-derived terms favored left detections likely because the first match the left-to-right eye trajectory that participants are routinely exposed to. Much like in research showing that increasing target frequency on one side over the other facilitates attention orientation (Hoffmann & Kunde, 1999), we show that habitualized rightward practices organically create expectancies regarding upcoming information and without the need for target probability formal instruction. Furthermore, attention was not evenly deployed across space (as one could assume if no bias of whatever sort operated) nor was it preferentially anchored on the left, as contended by biological accounts for the laterality of the visual system (Brooks et al., 2014). Quite the opposite, we observed a rightward attentional imbalance that, if anything, goes against the presumed biological left proclivity for attention allocation. Admittedly, only data from a right-to-left speaking sample would allow us to draw decisive conclusions (but see chapter IV for cross-cultural evidence in the mapping of time). However, the differentiated left-right performance suggests that an element of written language (script) is at play. We believe the present data is sufficiently robust to argue that scanning practices and other cultural directional regularities exert some form of attention control and that political words are efficient conduits in this relationship. The attentional bias driven by language direction was further attested across visual and auditory modalities. We observed no third-order interaction which suggests that the mental representation of political space is not affected by modality of stimulus input. In this sense, we replicate earlier findings showing that spatial representation of political words is of a conceptual, not linguistic, nature (Farias et al., 2013; and see Lakens et al., 2011 for similar evidence on time), but advance these results by revealing that linguistic and cultural practices modulate these mappings.

Previous research has concluded that political words are not merely dichotomously classified as pertaining to left and right poles but are instead charted with different spatial gradations across the semantic–symbolic representation (e.g., the word ‘communism’ is placed further to the left than the word ‘revolution’, Farias et al., 2013). A further nuance of our research is that we have acknowledged this semantic continuum and have tested whether the variance introduced by each word’s semantic meaning was accountable for the right-sided proneness. We found the words themselves to contribute very little to performance since they did not impede the emergence of visuomotor asymmetries. This means that conservatism-related words were no more likely to drive the rightward advantage than socialism-related words. Furthermore, other abstract categories have relational associations and experiential links to physical spatial representations (e.g., we are accustomed to seeing the number ‘1’ appearing before the number ‘2’; ‘Devil’ pictorially represented below ‘God’; calendars establishing a relation between the progression of time; etc.). Political words have little to no occasional co-occurrence with physical spatial experiences (e.g., it is nonsensical to assume that people are chronically exposed to the word ‘strike’ occurring before the word ‘dictatorship’) and yet have produced sizeable cueing effects. Unlike other abstract concepts that are topographically ordered (i.e., appearing in stable spatial relations to each other), politics do not form learned spatial configurations that can aid in performance. Because the politics-space association is rare, our results speak volumes about the degree to which space is embodied in political discourse. In addition to not explicitly conveying spatial information, the political words were presented centrally. This makes it unlikely that task-induced associations between stimuli and target locations may explain conceptual cueing effects (Proctor & Cho, 2006). There was also no overlap between word (‘left’ connoted and ‘right’ connoted) and target location (left and right) because the task was not to indicate the targets’ spatial location (which indeed could induce stimulus-response effects) but to discriminate between the letters p and q, irrespective of whether they appeared on the screen. Thus, whenever the target appeared on the right side of the screen, it could equiprobably be the letter q which is located left on the keyboard. We have additionally overruled handedness effects by showing that there is no facilitation in response time by responding with the left or right hands. Like Farias and colleagues (Farias et al., 2016) have shown, we also believe our results to be above any confound with stimulus-response compatibility and handedness effects.

Finally, it is relevant that political categories are fundamentally distinct from other abstract concepts grounding horizontally, like time. Despite convergent in the spatial mappings they induce, politics and time have a different genesis. Political spatial metaphors of left/right are relatively recent, as they originate in a metonymic use from 18th century French politics. Evidently, the concepts they generate do not hold the same accumulated exposure in everyday discourse than, say, those related with time. Additionally, political references are heavily context-dependent. The line separating ‘socialism’ and ‘conservatism’ categories is dynamic, as politics are ever-changing. This means that political terms can easily shift between categories and their interpretation lies greatly on the receiver more so than on the content of the word itself. The metaphor ‘time as space’, although susceptible to some cultural flexibility (Fuhrman & Boroditsky, 2010; Majid et al., 2013), is a remarkably transverse reference, making it a much more dependable abstract category. As mentioned above, politics have no observable link between source and concrete domains in the natural world (while, for instance, it is actually possible to perceive someone tall as more powerful). They are farther removed from space than time-related terms and still gave rise to comparable spatial associations. One of the significant contributions of this study, namely to embodiment perspectives, is that two (or more; additional evidence from other concepts is needed) categories of words semantically dissimilar in nature activate the same core attentional and cognitive processes (see chapter IV for converging evidence on time with the same task employed here). The common denominator to the output they generate is, to some extent, the directionality of reading habits.

These results carry practical contributions. Field practitioners in the areas of political marketing should consider incidental priming when placing stimuli in space. In the same vein, voting decisions can be influenced by the location of the polling station (Berger, Meredith, & Wheeler, 2008), and the order of candidates’ names on a ballot can influence election outcomes (Krosnick, Miller, & Tichy, 2004). The arrangement of visuals in line with script direction should not be overlooked if one’s goal is to foster attention, memory, and trust in the advertised ‘product’ (Hernandez et al., 2017; Monahan & Romero, 2020). With the contribute given by this study, the spatial grounding of politics has now been attested in a gamut of manipulations and tasks (posture manipulation, auditory disambiguation, semantic categorization) and political stimuli (words, images, party acronyms) (Dijkstra et al., 2012; Farias et al., 2013; Mills et al., 2015; Oppenheimer & Trail, 2010; van Elk et al., 2010). Notably, for the first time, we show that the same recursive activities of reading and writing that cause movement and agency perception (Suitner & Maass, 2016) bias metaphorical political language alike and across visual and auditory modalities. We conclude that the link between politics and horizontal space is unambiguously supplied by culture.

References

Anderson, S. F., Kelley, K., & Maxwell, S. E. (2017). Sample-size planning for more accurate statistical power: A method adjusting sample effect sizes for publication bias and uncertainty. *Psychological Science*, *28*(11), 1547–1562. https://doi.org/10.1177/0956797617723724

Barsalou, L. W. (2008). Grounded Cognition. *Annual Review of Psychology*, *59*(1), 617–645. https://doi.org/10.1146/annurev.psych.59.103006.093639

Boroditsky, L., & Ramscar, M. (2002). The roles of body and mind in abstract thought. *Psychological Science*, *13*(2), 185–189. https://doi.org/10.1111/1467-9280.00434

Brooks, J. L., Sala, S. Della, & Darling, S. (2014). Representational pseudoneglect: A review. *Neuropsychology Review*, *24*(4), 148–165. https://doi.org/10.1007/s11065-013-9245-2

Casasanto, D. (2009). Embodiment of abstract concepts: Good and bad in right- and left-handers. *Journal of Experimental Psychology: General*, *138*(3), 351–367. https://doi.org/10.1037/a0015854

Casasanto, D., & Boroditsky, L. (2008). Time in the mind: Using space to think about time. *Cognition*, *106*(2), 579–593. https://doi.org/10.1016/j.cognition.2007.03.004

Casasanto, D., & Jasmin, K. (2012). The hands of time: Temporal gestures in english speakers. *Cognitive Linguistics*, *23*(4), 643 – 674. https://doi.org/10.1515/cog-2012-0020

Dehaene, S., Bossini, S., & Giraux, P. (1993). The Mental Representation of Parity and Number Magnitude. *Journal of Experimental Psychology: General*, *122*(3), 371–396. https://doi.org/10.1037/0096-3445.122.3.371

Dijkstra, K., Eerland, A., Zijlmans, J., & Post, L. S. (2012). How body balance influences political party evaluations: A Wii balance board study. *Frontiers in Psychology*, *3*(DEC), 536. https://doi.org/10.3389/fpsyg.2012.00536

Estes, Z., Verges, M., & Barsalou, L. W. (2008). Head up, foot down: Object words orient attention to the objects' typical location: Research report. *Psychological Science*, *19*(2), 93–97. https://doi.org/10.1111/j.1467-9280.2008.02051.x

Farias, A. R., Garrido, M. V., & Semin, G. R. (2013). Converging modalities ground abstract categories: The case of politics. *PLoS ONE*, *8*(4), e60971. https://doi.org/10.1371/journal.pone.0060971

Farias, A. R., Garrido, M. V., & Semin, G. R. (2016). Embodiment of abstract categories in space. . . grounding or mere compatibility effects? The case of politics. *Acta Psychologica*, *166*, 49–53. https://doi.org/10.1016/j.actpsy.2016.03.002

Fitts, P. M., & Seeger, C. M. (1953). S-R compatibility: spatial characteristics of stimulus and response codes. *Journal of Experimental Psychology*, *46*(3), 199–210. https://doi.org/10.1037/h0062827

Fodor, J. (1975). *The language of thought*. Crowell.

Foroni, F., & Semin, G. R. (2009). Language that puts you in touch with your bodily feelings: The multimodal responsiveness of affective expressions. *Psychological Science*, *20*(8), 974–980. https://doi.org/10.1111/j.1467-9280.2009.02400.x

Fuhrman, O., & Boroditsky, L. (2010). Cross-cultural differences in mental representations of time: Evidence from an implicit nonlinguistic task. *Cognitive Science*, *34*(8), 1430–1451. https://doi.org/10.1111/j.1551-6709.2010.01105.x

Gallese, V. (2008). Mirror neurons and the social nature of language: The neural exploitation hypothesis. *Social Neuroscience*, *3*(3–4), 317–333. https://doi.org/10.1080/17470910701563608

Garrido, M. V., Farias, A. R., & Palma, T. (2010). "O Espaço da política": Avaliação da conotação política e da valência de uma lista de palavras. *Laboratório de Psicologia*, *8*(1), 81–99. https://doi.org/10.14417/lp.650

Glenberg, A. M., & Gallese, V. (2012). Action-based language: A theory of language acquisition, comprehension, and production. *Cortex*, *48*(7), 905–922. https://doi.org/10.1016/j.cortex.2011.04.010

Glenberg, A. M., & Kaschak, M. P. (2002). Grounding language in action. *Psychonomic Bulletin and Review*, *9*(3), 558–565. https://doi.org/10.3758/BF03196313

Goodsell, C. T. (1988). The architecture of parliaments: Legislative houses and political culture. *British Journal of Political Science*, *18*(3), 287–302. http://www.jstor.org/stable/193839

Hernandez, M. D., Wang, Y., Sheng, H., Kalliny, M., & Minor, M. (2017). Escaping the corner of death? An eye-tracking study of reading direction influence on attention and memory. *Journal of Consumer Marketing*, *34*(1), 1–10. https://doi.org/10.1108/JCM-02-2016-1710

Hoffmann, J., & Kunde, W. (1999). Location-specific target expectancies in visual search.

Journal of Experimental Psychology: Human Perception and Performance, *25*(4), 1127–1141. https://doi.org/10.1037/0096-1523.25.4.1127

Ijzerman, H., & Semin, G. R. (2009). The thermometer of social relations: Mapping social proximity on temperature: Research article. *Psychological Science*, *20*(10), 1214–1220. https://doi.org/10.1111/j.1467-9280.2009.02434.x

Jostmann, N. B., Lakens, D., & Schubert, T. W. (2009). Weight as an embodiment of importance. *Psychological Science*, *20*(9), 1169–1174. https://doi.org/10.1111/j.1467-9280.2009.02426.x

Kan, I. P., Barsalou, L. W., Solomon, K. O., Minor, J. K., & Thompson-Schill, S. L. (2003). Role of mental imagery in a property verification task: fMRI evidence for perceptual representations of conceptual knowledge. In *Cognitive Neuropsychology* (Vol. 20, Issues 3–6, pp. 525–540). Cogn Neuropsychol. https://doi.org/10.1080/02643290244000257

Kaschak, M. P., & Borreggine, K. L. (2008). Temporal dynamics of the action-sentence compatibility effect. *Quarterly Journal of Experimental Psychology*, *61*(6), 883–895. https://doi.org/10.1080/17470210701623852

Knoblich, G., & Flach, R. (2001). Predicting the effects of actions: Interactions of Perception and Action. *Psychological Science*, *12*(6), 467–472. https://doi.org/10.1111/1467-9280.00387

Lakens, D., Semin, G. R., & Garrido, M. V. (2011). The sound of time: Cross-modal convergence in the spatial structuring of time. *Consciousness and Cognition*, *20*(2), 437–443. https://doi.org/10.1016/j.concog.2010.09.020

Lakoff, G., & Johnson, M. H. (1980). The metaphorical structure of the human conceptual system. *Cognitive Science*, *4*, 195–208. https://doi.org/10.1016/S0364-0213(80)80017-6

Landauer, T. K., & Dumais, S. T. (1997). A Solution to Plato's Problem: The Latent Semantic Analysis Theory of Acquisition, Induction, and Representation of Knowledge. *Psychological Review*, *104*(2), 211–240. https://doi.org/10.1037/0033-295X.104.2.211

Maass, A., Pagani, D., & Berta, E. (2007). How beautiful is the goal and how violent is the fistfight? Spatial bias in the interpretation of human behavior. *Social Cognition*, *25*(6), 833–852. https://doi.org/10.1521/soco.2007.25.6.833

Maass, A., & Russo, A. (2003). Directional Bias in the Mental Representation of Spatial Events: Nature or Culture? *Psychological Science*, *14*(4), 296–301. https://doi.org/10.1111/1467-

9280.14421

Majid, A., Gaby, A., & Boroditsky, L. (2013). Time in terms of space. *Frontiers in Psychology, 4*, 554. https://doi.org/10.3389/fpsyg.2013.00554

Meier, B. P., & Robinson, M. D. (2004a). Why the sunny side is up: Associations between affect and vertical position. *Psychological Science*, *15*(4), 243–247. https://doi.org/10.1111/j.0956-7976.2004.00659.x

Meier, B. P., & Robinson, M. D. (2004b). Why the Sunny Side Is Up: Associations Between Affect and Vertical Position. *Psychological Science*, *15*(4), 243–247. https://doi.org/10.1111/j.0956-7976.2004.00659.x

Meteyard, L., Bahrami, B., & Vigliocco, G. (2007). Motion detection and motion verbs: Language affects low-level visual perception. *Psychological Science*, *18*(11), 1007–1013. https://doi.org/10.1111/j.1467-9280.2007.02016.x

Mills, M., Smith, K. B., Hibbing, J. R., & Dodd, M. D. (2015). Obama cares about visuo-spatial attention: Perception of political figures moves attention and determines gaze direction. *Behavioural Brain Research*, *278*, 221–225. https://doi.org/10.1016/j.bbr.2014.09.048

Monahan, L., & Romero, M. (2020). Heading the right way? The influence of motion direction in advertising on brand trust. *Journal of Advertising*, *49*(3), 250–269. https://doi.org/10.1080/00913367.2020.1751010

Oppenheimer, D. M., & Trail, T. E. (2010). Why leaning to the left makes you lean to the left: Effect of spatial orientation on political attitudes. *Social Cognition*, *28*(5), 651–661. https://doi.org/10.1521/soco.2010.28.5.651

Ouellet, M., Santiago, J., Funes, M. J., & Lupiáñez, J. (2010). Thinking about the future moves attention to the right. *Journal of Experimental Psychology: Human Perception and Performance, 36*(1), 17–24. https://doi.org/10.1037/a0017176

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (2010). Is the future the right time? *Experimental Psychology*, *57*(4), 308–314. https://doi.org/10.1027/1618-3169/a000036

Posner, M. I. (1980). Orienting of attention. *The Quarterly Journal of Experimental Psychology*, *32*(1), 3–25. https://doi.org/10.1080/00335558008248231

Richardson, D. C., Spivey, M. J., Barsalou, L. W., & McRae, K. (2003). Spatial representations activated during real-time comprehension of verbs. *Cognitive Science*, *27*(5), 767–780.

https://doi.org/10.1016/S0364-0213(03)00064-8

Román, A., Flumini, A., Lizano, P., Escobar, M., & Santiago, J. (2015). Reading direction causes spatial biases in mental model construction in language understanding. *Scientific Reports, 5,* 18248. https://doi.org/10.1038/srep18248

Ruiz Fernández, S., Rahona, J. J., Hervás, G., Vázquez, C., & Ulrich, R. (2011). Number magnitude determines gaze direction: Spatial-numerical association in a free-choice task. *Cortex*, *47*(5), 617–620. https://doi.org/10.1016/j.cortex.2010.10.006

Santiago, J., Lupiáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin and Review, 14,* 512–516. https://doi.org/10.3758/BF03194099

Santiago, J., Román, A., Ouellet, M., Rodríguez, N., & Pérez-Azor, P. (2010). In hindsight, life flows from left to right. *Psychological Research*, *74*(1), 59–70. https://doi.org/10.1007/s00426-008-0220-0

Schubert, T. W. (2005). Your highness: Vertical positions as perceptual symbols of power. *Journal of Personality and Social Psychology, 89*(1), 1–21. https://doi.org/10.1037/0022-3514.89.1.1

Sell, A. J., & Kaschak, M. P. (2012). The comprehension of sentences involving quantity information affects responses on the up-down axis. *Psychonomic Bulletin and Review, 19*(4), 708–714. https://doi.org/10.3758/s13423-012-0263-5

Semin, G. R., & Palma, T. A. (2014). Why the bride wears white: Grounding gender with brightness. *Journal of Consumer Psychology*, *24*(2), 217–225. https://doi.org/10.1016/j.jcps.2013.09.003

Shaki, S., Fischer, M. H., & Petrusic, W. M. (2009). Reading habits for both words and numbers contribute to the SNARC effect. *Psychonomic Bulletin and Review*, *16*(2), 328–331. https://doi.org/10.3758/PBR.16.2.328

Sherman, G. D., & Clore, G. L. (2009). The color of sin: White and black are perceptual symbols of moral purity and pollution. *Psychological Science, 20*(8), 1019–1025. https://doi.org/10.1111/j.1467-9280.2009.02403.x

Suitner, C., & Maass, A. (2016). Spatial agency bias: Representing people in space. *Advances in Experimental Social Psychology*, *53*, 245–301. https://doi.org/10.1016/bs.aesp.2015.09.004

van Elk, M., van Schie, H. T., & Bekkering, H. (2010). From left to right: Processing acronyms referring to names of political parties activates spatial associations. *Quarterly Journal of Experimental Psychology*, *63*(11), 2202–2219. https://doi.org/10.1080/17470218.2010.495160

Weger, U. W., & Pratt, J. (2008). Time flies like an arrow: Space-time compatibility effects suggest the use of a mental timeline. *Psychonomic Bulletin and Review*, *15*(2), 426–430. https://doi.org/10.3758/PBR.15.2.426

Zwaan, R. A. (2004). The immersed experiencer: Toward an embodied theory of language comprehension. In *The Psychology of Learning and Motivation: Advances in Research and Theory, Vol. 44.* (pp. 35–62). Elsevier Science.

Chapter VI.
The effect of simultaneously presented words and auditory tones on visuomotor performance

Chapter based on:

Mendonça, R., Garrido, M. V., & Semin, G. R. (revise and resubmit). The effect of simultaneously presented words and auditory tones on visuomotor performance. *Multisensory Research.*

Abstract

The experiment reported here used a variation of the spatial cueing task to examine the effects of unimodal and bimodal attention orienting primes on target identification latencies and eye-gaze movements. The primes were a nonspatial auditory tone and words known to drive attention consistent with the dominant writing and reading direction, as well as introducing a semantic, temporal bias (past-future) on the horizontal dimension. As expected, past-related (visual) word primes gave rise to shorter response latencies on the left hemifield and future-related words on the right. This congruency effect was differentiated by an asymmetric performance on the right space following future words and driven by the left-to-right trajectory of scanning habits that facilitated search times and eye-gaze movements to lateralized targets. Auditory tone prime alone acted as an alarm signal, boosting visual search and reducing response latencies. Bimodal priming, i.e., temporal visual words paired with the auditory tone, impaired performance by delaying visual attention and response times relative to the unimodal visual word condition. We conclude that bimodal primes were no more effective in capturing participants' spatial attention than the unimodal auditory and visual primes. Their contribution to the literature on multisensory integration is discussed.

Keywords

Attention; Spatial Agency Bias; Multisensory Integration; Vision; Audition.

Introduction

This research was designed to examine how distinct stimuli, namely nonspatial auditory tones and visual temporal words, can modulate visual attention when presented concurrently. Research has produced conflicting reports on whether bimodal cues capture attention more effectively than unimodal cues (see Spence and Santangelo, 2009 for a review). Audiovisual bimodal cues seem to delay visual processing relative to unimodal events (Driver and Spence, 1998; Mcgurk and Macdonald, 1976; Spence and Driver, 1997) because task demands increase and processing is equally impeded in both modalities (Robinson et al., 2018; Shams et al., 2002). However, other research has shown that auditory tones temporally colocalized with visual targets drastically reduce visual search latencies (Dalton and Spence, 2007; Van der Burg et al., 2008; Vroomen and De Gelder, 2000).

The current study examines whether bimodal primes composed of a visual word and an auditory tone facilitate attention and target discrimination over their single unimodal presentation. We used a bimodal cueing task with time words priming horizontal locations consistent with the semantic indication (past-left/future-right in ‘Western’ languages, Lakens et al., 2011) and biased by the culturally-defined reading and writing direction (Suitner and Maass, 2016), and a location free auditory prime previously shown to accelerate visual search towards the location of a synchronized visual event (Ngo and Spence, 2010; Vroomen and De Gelder, 2000).

The experimental task is inspired by previous research but introduces a manipulation in which audiovisual primes were concurrently presented at cue level. We hypothesized that co-occurring modalities would support each other to produce multisensory integration that would enhance motor and gaze performance over single modality trials. In bimodal trials, the co-occurring auditory tone should enhance the attentional and motor effects generated by the spatial grounding of words, particularly for ‘rightward’ time words (i.e., future-related) that are aligned with the habitual language direction.

In the following, we provide a brief overview of the literature on the spatial biases induced by reading and writing habits and the semantic, temporal bias words. We then turn to the literature on the attention-capturing features of auditory tones and multimodal stimuli. After concluding the introduction, we provide an overview of the research.

Contributors to Attentional and Cognitive Biases

Culturally habitualized routines constitute one of the major influences on how a substantive range of processes comprising representation, attention, and cognition are shaped. In particular, reading and writing are the typical activities that fall into the category of habit formation. The influence of these activities can be in opposing directions as in the case of, for example, European languages (left to right reading-writing) versus Arabic linguistic communities and Hebrew (right to left). Consequently, these cultural habits can give rise to systematic representational, attentional, and cognitive biases. Similarly, specific conceptual categories, such as time (Lakens et al., 2011; Majid et al., 2013; Santiago et al., 2007), but also politics (Farias et al., 2016; Mills et al., 2015), or numbers (Shaki et al., 2009; Zebian, 2005) can exercise an influence in the way attention is directed. In most Western communities, time is anchored on a horizontal dimension evolving from left to right (past/left versus future/right; e.g., Ouellet et al., 2010a; Santiago et al., 2010).

Notably, multisensory primes produce additive effects over unimodal primes. These lead to gains in attention orienting because the conjugation of, for instance, two modalities intensifies attentional effects (Alvarado et al., 2007; Teder-Sälejärvi et al., 2002). One special case is when a location free auditory signal is paired with a visual target (Talsma et al., 2010; Van der Burg et al., 2008). In short, we have three types of attention driving factors that overlap:

1. The dominant reading and writing system shapes how attentional direction unfolds on a horizontal trajectory influencing among other things psychological variables such as agency and movement (e.g., Spatial Agency Bias, Suitner and Maass, 2016);
2. The grounding of specific abstract concepts such as time on a horizontal space (Fuhrman and Boroditsky, 2010; Lakens et al., 2011; Ouellet et al., 2010b);
3. Nonspatial auditory signals that have been shown to improve detection of a synchronously presented visual target (e.g., Dalton and Spence, 2007; Van der Burg et al., 2008; Vroomen and De Gelder, 2000)

In the following, we detail briefly the empirical evidence for the three attention driving factors, as well as for their integration in multimodal research. Before proceeding with the three sources driving attention, we should briefly mention presumed biological influences on spatial attention. It has been argued that in spatial tasks, the right hemisphere is dominant in generating a predisposition to attend to the left hemispace (Brooks et al., 2014). For instance, neurologically normal individuals bisect a horizontal line by erring slightly to the left of a line's midpoint (i.e. pseudoneglect) (see Jewell and McCourt, 2000 for a review). In free exploration of images, the initial bias has been found to the left visual field (Ossandón et al., 2014), and asymmetrical scanning of visual space has been reported (Butler and Harvey, 2006). The biologically determined account has however been challenged by studies with native readers of right-to-left languages (Afsari et al., 2018; Rashidi-Ranjbar et al., 2014) or bilingual populations with opposite script directions, who have shown minimal lateralization (Hernandez et al., 2017; Kermani et al., 2018).

Reading and Writing Systems

The influence of culturally anchored reading and writing direction has been shown across a wide range of psychological processes starting with asymmetrical scanning routines, to ascription of agency. Script direction guides attention because people typically start scanning space where writing begins. Eyes and hand progress together in space which creates a correlation between space and the occurrence of future information. The dominant writing system has been shown to shape the representation of action (Suitner and Maass, 2016). For example, participants from rightward flowing languages typically place the agent of a sentence to the left in thematic-role drawing tasks (Maass and Russo, 2003). These effects are also carried over to artwork aesthetic preferences (Chahboun et al., 2017; Smith et al., 2020), interpretation of films and football games (Maass et al., 2007), stereotypical representation of groups (Maass et al., 2009), gender categorization (Suitner et al., 2017), and memory (Bettinsoli et al., 2019). Reading and writing habits establish an enduring preferential scanning of space (Afsari et al., 2018; Chokron and De Agostini, 2000). Therefore, the anticipation of future information is facilitated when it coincides with script direction because people expect stimuli to flow in accordance with momentum (Hubbard, 2005).

Grounding the Abstract Concept of Time

In contrast to reading and writing habits, the grounding of abstract concepts such as time lacks direct sensory-based experience. However, across most cultures time is anchored spatially (Bergen and Lau, 2012; e.g., Boroditsky et al., 2011; Tversky et al., 1991). In cultures with left-to-right orthography, time is grounded by a rightward movement (e.g., European languages). In cultures with right-to-left orthography (e.g., Arabic/Hebrew-speaking cultures) time moves leftward (Fuhrman and Boroditsky, 2010). Although there are other cultural variations on how time is grounded (e.g., time is mapped in cardinal directions, Boroditsky and Gaby, 2010; time is on a vertical axis, Lai and Boroditsky, 2013; time is uphill or downhill, Núñez et al., 2012), space is the common denominator, and directionality and location of past and future vary as a function of a culture's orthographic or ecological properties. Studies employing verbal information revealed that exposure to past and future terms in left-to-right orthography facilitates motor and attentional responses to the left and right space (Ouellet et al., 2010a; Santiago et al., 2007; Torralbo et al., 2006; Weger and Pratt, 2008). The same effect emerges when time categories are presented auditorily irrespective of orthographic directionality

(Ouellet et al., 2010b). This research shows that not only the reading and writing convention for text direction guides temporal mappings, but that temporal words are effective media to prime scanning directions as a function of time-space associations.

Auditory Cues as Attention Drivers

Aside from the two aforementioned attention driving endogenous factors, exogenous ones such as auditory warning signals (Ho and Spence, 2005) have attention capturing properties. The characteristics of exogenous cues is that they are typically non-semantic in nature (e.g., abrupt onset like a flash of light or a sound burst). They barely carry spatial information, but when they are delivered near the location of the impending target (in cued trials), target detection is facilitated. It has also been argued that exogenous cues increase alertness (Fernandez-Duque and Posner, 1997) since conditions with these cues produce faster responses than conditions without them. Additionally, nonspatial auditory tones when concurrently presented with visual targets increase the target's salience and guide attention towards a visual change (Ngo et al., 2012; Ngo & Spence, 2010; Van der Burg et al., 2008).

Multimodal Cues and Attention Capturing

Research on the capacity for multimodal cues to retain attention-capturing capabilities has produced conflicting reports (see Spence and Santangelo, 2009 for a review). Simultaneous input from different sensory modalities seem to support each other to produce multisensory interactions that are additive, and which may alter cueing effects (Alvarado et al., 2007; Laurienti et al., 2005) even when multimodal information is redundant (Selcon et al., 1995). Multimodal events enhance responses of the superior colliculus neurons (a brain structure involved in the overt orienting of the eyes and head) above those evoked by the sum of the unimodal stimuli components (Wallace et al., 1998). However, research has struggled to demonstrate the bimodal advantage in behavioral tasks (Santangelo et al., 2006; Ward et al., 1998). In a seminal study, Ward (1994) presented audiovisual cues peripherally to participants and reported numerically larger (but not statistically significant) cueing effects over the most effective unimodal element. In an elevation discrimination task immune to stimulus-response overlap that Ward did not control for, Spence and Driver (1997) were not able to report an advantage of audiovisual primes to capture attention relative to the best unimodal primes. Others have also reported negligible differences in speeded responses between unimodal and bimodal presentations (Ho et al., 2009, Exp. 1; Santangelo et al., 2006; Santangelo and Spence, 2008).

Stimuli in one modality can alter the processing of other sensory input (Shams et al., 2002; Sloutsky and Napolitano, 2003). Most research has pointed to visual dominance in adults (see Spence et al., 2011 for a review). While vision is the dominant modality by default in spatial tasks (see Welch and Warren, 1986 for a review), there is evidence that audiovisual cues promote auditory dominance in auditory responses (Barnhart et al., 2018). The asymmetry in modality performance can owe it to task demands and the preparedness they instigate in the observer to process either modality (Robinson et al., 2018). This may cause distinct sensory input to compete for attentional resources and preclude super-additive effects to emerge.

The Present Study

The current research investigates whether bimodal, relative to unimodal, primes can efficiently capture attention and facilitate speeded responses to lateral targets. The novelty of this study is that it brings together distinct but interrelated research traditions on attention-orienting primes showing that: a) movement (i.e. agency) representation is affected by consistent exposure to script direction in a given culture, as are other categories grounded in the same left-right continuum (i.e. time) (Suitner and Maass, 2016); b) temporal language induces a semantic bias in visuomotor responses on the left/right coordinates (e.g., Ouellet et al., 2010a; Torralbo et al., 2006); c) nonspatial auditory tones co-occurring with visual events enhance visual search (Van der Burg et al., 2008); and d) multisensory stimuli interact to product additive cueing effects (e.g., Alvarado et al., 2007; Teder-Sälejärvi et al., 2002).

In a spatial cueing task, we examined the effects of unimodal (auditory tone alone; visual time-related word alone) and bimodal primes (concurrent presentation of visual word and auditory tone) on lateralized target identification. A condition without prime was also included. From the integration of the aforementioned research on the factors that guide attention, we have derived the following specific hypotheses:

H1: The spatial information of temporal words should drive attention to and produce faster identification of target positions congruent with their horizontal grounding (past word-left target, future word-right target).

H2: The pressure exerted by the rightward orthographic directionality (in European linguistic communities) should produce a unidirectional influence on attention orienting. This unidirectional influence, when combined with words that have a rightward connotation (i.e., future) is expected to benefit from this script habitualization. These combined biases are expected to accelerate responses on the right hemifield to a greater extent than past words on the left. That is, we should observe a semantic congruency effect (H1) but overall, a precedence of the orthographic directionality that differentiates between congruent presentations.

H3: The nonspatial auditory tone, when presented in isolation in the unimodal condition, would act as a warning signal and facilitate attention and target identification over the absence of target presentation.

H4: Without prejudice to asymmetric performance (H2), bimodal presentation (i.e., concomitant auditory and word primes) relative to unimodal visual presentation (i.e., word) is expected to produce an enhanced multisensory interaction that facilitates attention and speeds up target identification.

This study advances prior research in several respects. The bimodal prime elements are very different in their attention-grabbing properties and are not frequently paired in multimodal research. The bimodal primes combine a typical exogenous cue (i.e., auditory nonspatial tone) and a typical endogenous or symbolic cue (i.e., directional time word). The auditory tone was presented binaurally creating an essentially unlocalizable source (see Spence and Driver, 1997 for a similar example with loudspeakers). The words were meaning-based but not conventional like other spatial pointers. Aside from their modality, these primes could not conflict as the auditory tone is devoid of any inherent spatial information. This circumvents problems encountered in prior studies, for instance with conflicting directional information conveyed by the two simultaneous modalities. Thus, the study makes an empirical contribution to the literature on multimodal cueing, which has yet not been able to show whether there is a clear advantage of bimodal over unimodal primes.

Method

Participants

Participants were fifty-four undergraduate students who were compensated with course credit (M_{age} = 23.70, SD_{age} = 5.50). Sample size was determined based on the effect size proposed for temporal priming tasks (von Sobbe et al., 2019) for a repeated measures within-subjects ANOVA using BUCSS R method (Anderson et al., 2017) adjusting effects for uncertainty and publication bias (desirable level of assurance = .90; statistical power = .80). Participants were screened for normal visual acuity and reported no hearing problems. Five participants were excluded because they were nationals of countries other than Portugal. All the remaining participants (n = 49) were Portuguese native speakers and had not spent any significant time in right-to-left speaking countries. The experiment was approved by the Ethics Committee of the host institution and participants gave their informed written consent.

Primes

Attention orienting primes were four distinct kinds: no prime, auditory tone alone, visual time-related word alone, and visual time-related word co-occurring with an auditory tone. Visual stimuli consisted of 24 words from a list of Spanish time-relevant words previously used by other authors (e.g., Ouellet et al., 2010b; Torralbo et al., 2006). Words comprised 8 past- and 8 future-related words. The remaining 8 words were neutral and generated by us. Neutral words carried temporal meaning but lacked temporal directionality (see Appendix 1 for the extensive word list). The future and past word sets comprised 1 verb inflected in either the past ("it was" – "foi") or future tense ("it will" – "será"), and 7 past (e.g., "before" – "antes") or future temporal adverbs (e.g., ''after'' – "depois"). The neutral time-related word set was composed of nouns (e.g., "month" – "mês"). Four additional words were used for the practice trials. To establish their temporal meaning, the words were translated and piloted on a Portuguese speaking sample (n = 99). The words were individually and randomly presented to the participants at the center of the screen. Below each word, there was a horizontal line and a slider bar that participants were asked to place where they thought best represented the temporal meaning conveyed by the word (0 = *far past*; 100 = *far future*). Participants did not see the polar labels. They were presented with the horizontal line and a slider bar positioned on the scale's midpoint just below the word "present", which symbolized the present moment. Importantly, the words were selected such that they reflected different gradations of the temporal continuum, that is, they ranged from far past/future to immediate past/future. The words were grouped according to their mean ratings and their temporal orientation was found to be significantly different, F (2, 21) = 79.281, $p < .001$, ($M_{\text{past-oriented}} = 22.64$, $SD_{\text{past-oriented}} = 3.83$; $M_{\text{neutral}} = 56.73$, $SD_{\text{neutral}} = 1.49$; $M_{\text{future-oriented}} = 75.81$, $SD_{\text{future-oriented}} = 3.25$; p*'s* $\leq .001$ between groups). Each word was presented four times throughout the experiment: twice alone, and twice paired with the auditory tone.

As auditory stimuli, we used a short non-informative auditory tone of 500-Hz tone (44.1 kHz sample rate, 16 bit, mono) with a duration of 60 ms (Van der Burg et al., 2008). The tone was binaurally presented via headphones either alone or concurrently with the visual word primes at the center of the screen, that is, auditory prime and visual prime had the same onset.

Targets

The targets were two strings of five letters simultaneously presented to the left and the right sides of the screen midpoint, at ±13.31° of eccentricity. This means the target sets were in the near peripheral left and right visual fields which ensured that participants could not discriminate the target unless gaze movements were made (i.e. overt attention). The target letter strings subtended 4.77° of visual angle. The target letter was either a *p* or a *q* embedded in one of the two letter strings (1 target and 4 distractors on one side, 5 distractors on the opposite side). The distractors were kept constant across the experiment. The distractors' and the targets' positions within the stream were varied randomly across trials. As there were two possible targets but only one correct answer per trial, the task required discrimination rather than mere detection. This setup allows us to rule out cueing effects as emerging from stimulus-response compatibility, a correspondence between target location and response effector. This is because the location of the target key on the gamepad had a 50:50 chance to coincide with the location of the target letter on the left or right sides of the screen. Additionally, there were two bilateral letter sets instead of a single lateralized target. By doing so, we ensured that participants gazed towards both sides to actively look for the target, instead of systematically looking at one side and inferring the target from there.

Apparatus and Display

The task was programmed using Experiment Builder (Version 1.10.1630, SR Research, 2016). An Eyelink 1000 plus eye tracker (SR Research) with a sampling rate of 1000 Hz was calibrated to the participants' dominant eye, but viewing was binocular. Calibration was performed with a five-point procedure, with 0.5° average accuracy for all points. Calibration was repeated whenever the error at any point was higher than 1°. A chinrest was set at 60 cm to the screen to prevent participants from moving their head. Responses were collected through a standard gamepad with keys marked *p* and *q*. The auditory stimulus was administered via headphones.

Procedure

A modification of a spatial cueing paradigm was used to combine both visual (words) and auditory (single tone) modalities. The task was run individually at the university's laboratory. Instructions informed participants that both the auditory tone and the visual words were uninformative of target location. They were told their task was simply to discriminate the target letters embedded in the letter strings, which would appear after the prime presentation. The general instruction was a speed-accuracy one (See Fig. 1 for a trial example). Participants placed their index fingers on the response keys and were asked to press them as soon as they detected a *q* or a *p*. Each trial began with a gaze-contingent fixation cross (0.3° × 0.3°), therefore the next screen would only be triggered after a minimum fixation of 1000 ms. This procedure ensured that the starting point of eye movements was at the center of the display, thus preventing attention to be oriented elsewhere prior to trial onset. A blank screen was presented for 500 ms which was followed by the presentation of one of the four possible prime combinations for 700 ms: no prime, auditory tone, visual word, or visual word + auditory tone (the auditory tone lasted 60 ms and tone and word had the same onset). Both in the prime-absent and the auditory tone conditions, a fixation cross was presented at the center of the display to anchor the initial gaze movement of participants for visual search. An interstimulus interval screen of 150 ms followed. The next screen was the target display where the two letter strings (one of which containing the *p* or *q*) appeared on the left and right visual fields for 1000 ms. A screen with a feedback message followed for 800 ms. After the feedback message disappeared, a blank screen was presented for 500 ms and a new trial began.

Each block consisted of 96 trials randomly presented, divided by 4 groups of 24 trials composed of the 4 prime categories. Within each 24 trial subset, the target was counterbalanced for letter (*p* or *q*) and location (left or right) making the target location non-predictive. Thus, the ratio of valid and invalid trials was 50:50. This means that participants could not infer the target location by attending to the meaning of the words. All factors were equiprobable and presented in a counterbalanced order. The experiment comprised 2 blocks resulting in a total of 192 trials. Participants took a self-paced break between blocks followed by a recalibration. Twelve practice trials following the same counterbalancing schema preceded the main experiment. On average, the experiment was completed in 45 minutes.

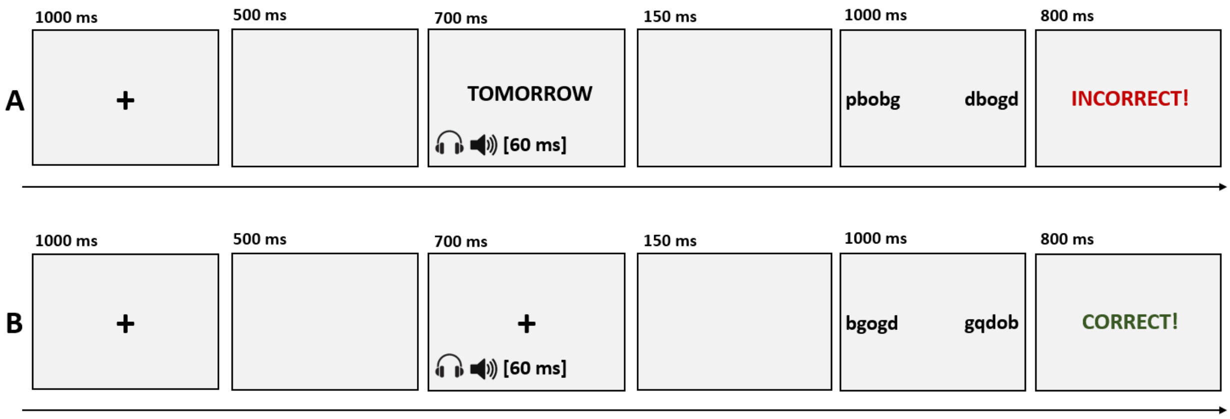

Figure 1. Panel A shows and example of a trial with bimodal cueing (time word + auditory tone) and panel B shows an example of a trial with unimodal auditory cueing (auditory tone).

Results

Preliminary Data Treatment

We flagged outliers based on values surpassing 2.5 median absolute deviations (MAD) (Leys et al., 2013). No participant was excluded as mean responses did not exceed 25% of outlier values (maximum outlier values per participant ≤ 17%). The outlier values (< 1% of data across all the analyzed variables) were then replaced by one unit above the next extreme score on that variable. Two rectangular areas of interest (AOI) were designed around the left and right target letter streams but were not visible to the participants.

Statistical Analysis

We compared both manual performance (i.e. response times), and gaze movement (i.e. average saccade velocity, direction of the first saccade, and first fixation onset) in within-subjects repeated-measures analyses of variance (ANOVAs). Post-hoc comparisons were performed using the Bonferroni correction procedure. The four types of primes are fundamentally distinct and therefore it would not be suitable to compare them directly. We split them into two clear clusters and analyzed them accordingly: primes without semantic content (i.e. no prime; auditory tone) and primes with semantic content (i.e. visual word cues; visual word cue + auditory tone).

Reaction Time

To directly tackle our main claim that orthographic directionality, temporal language and multimodal presentation interact to shape motor performance, we start by reporting the analysis for primes with semantic content. These factors were compared within-subjects in a 2x3x2 design: prime type (visual word primes vs. visual word primes + auditory tone) x word category (past vs. neutral vs. future) x target letter location (left vs. right).

First, we report main effects of prime type, $F\ (1, 48) = 32.563$, $p < .001$, $\eta_p^2 = .40$, and word category, $F\ (2, 96) = 5.587$, $p = .005$, $\eta_p^2 = .10$. Contrary to what we predicted (H4), visual words presented alone gave rise to faster response times (M = 696.86, SE = 5.60) than when concurrently presented with the auditory prime (M = 732.90, SE = 5.61). As for the temporal category of the word primes, future-related words generated significantly faster target identification (M = 699.03, SE = 6.65) than past-related (M = 723.24, SE = 6.23; $p = .004$) and temporally neutral words (M = 722.37, SE = 6.98; $p = .007$). Past-related and neutral words did not generate different response times ($p = 1.000$). This latter main effect confirms our predictions regarding the rightward pressures exerted by the orthographic system (H2).

The significant interaction of word category x target location confirms the time-space congruency hypothesis (H1), F (2, 96) = 10.937, $p < .001$, $\eta_p^2 = .19$. An inspection of the means reveals the typical congruency effect, in that identification of targets was systematically faster when the target location was consistent with temporal connotation of the word (Fig. 2). However, this tendency was only significant following future-related words; targets on the right (M = 677.79, SE = 9.82), that is on the side consistent with the word indication, were identified faster than targets on the left (M = 720.26, SE = 10.66; p = .009). The remaining target identification latencies on the left and right sides were not significantly different following past-related (left: M = 711.14, SE = 9.62; right: M = 735.35, SE = 12.26; p = .189) and neutral words (left: M = 718.63, SE = 8.80; right: M = 726.11, SE = 12.91; p = .664). This means that congruency effects were only significant following rightward words, although a similar but statistically nonsignificant pattern can also be observed for past-related words.

Following from the previous second-order interaction, and to explore whether there was an asymmetric performance in responding favoring words with rightward connotation (H2), we compared congruent conditions of past word – left target and future word – right target. A paired samples t-test revealed that future-related words produced marginally faster detections of the right target than past-related words of the left target, t (48) = -1.964, p = .055).

The third-order interaction between prime type x word category x target location, that brings together the research models known to drive attention (H1 + H2 + H4), was significant, F (2, 96) = 3.682, p = .029, $\eta_p^2 = .07$. We start by reporting results for the unimodal prime condition, i.e., time words alone. Identification latencies were significantly shorter for the side of space that was congruent with the implied directionality of the time-relevant word. Targets on the left (M = 675.10, SE = 12.04) relative to the right (M = 723.81, SE = 16.93; p = .049) were detected faster after a past-relevant word was presented. Similarly, but with an amplified mean difference, response times were facilitated following a future-related word for targets on the right (M = 644.56, SE = 11.68) than on the left (M = 701.22, SE = 12.46; p = .002). Neutral words presented alone did not produce different response times across the left and right targets (p = .715). Finally, we report the cueing effects following bimodal primes, i.e., time-relevant words presented jointly with the auditory tone. Against our predictions (H4), identification latencies in audiovisual prime conditions did not vary for left and right targets as a function of the category of the words (all p's > .126).

Finally, we report the analysis of the primes without semantic content. To address the hypothesis that the auditory tone serves an alertness purpose (H3), correct response times were compared in a 2 (prime type: no prime vs. auditory tone) x 2 (target letter location: left vs. right) repeated measures ANOVA. A significant main effect of prime type was observed, F (1, 48) =

70.043, $p < .001$, $\eta_p^2 = .59$. As predicted, exposure to the auditory tone led to significantly shorter response latencies in detecting the target letter (M = 735.02, SE = 6.43) compared to the silent condition, that is in the absence of a prime (M = 786.84, SE = 6.83) (Fig. 3). The target location did not generate significantly different identification latencies, F (1, 48) = .114, p = .735. Similarly, response times were not significantly different across left and right hemifields as a function of the type of prime, F (1, 48) = 3.333, p = .074.

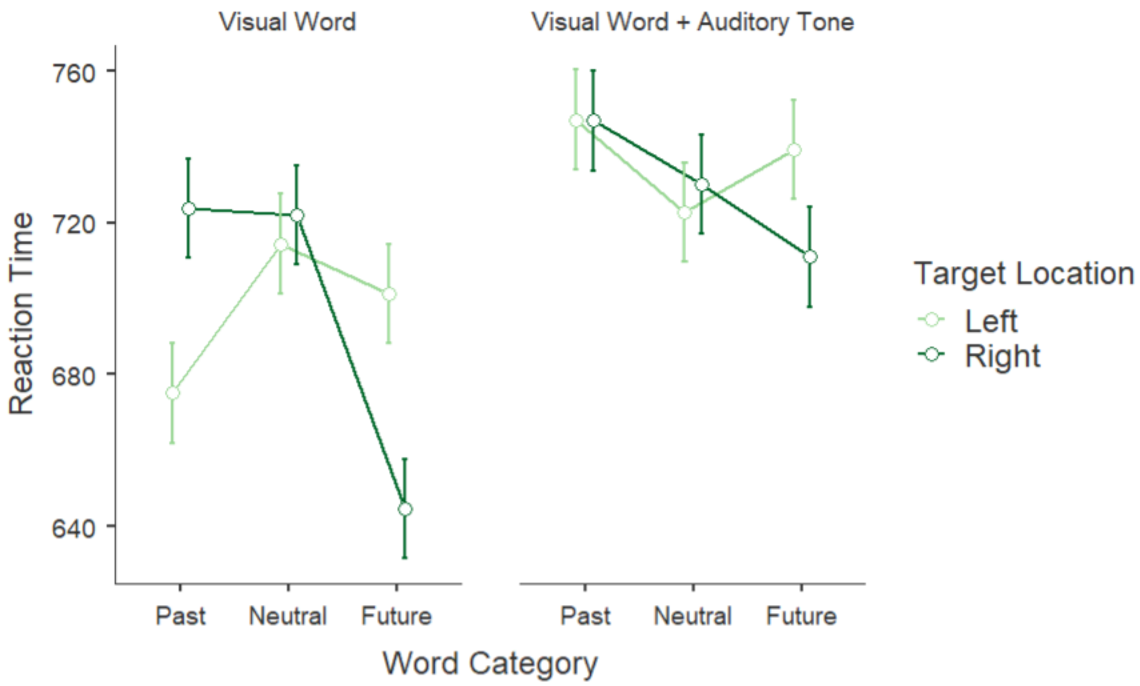

Figure 2. Mean response time (in milliseconds) as a function of primes with semantic content, time-related word category, and target location. Error bars represent the standard error from the mean.

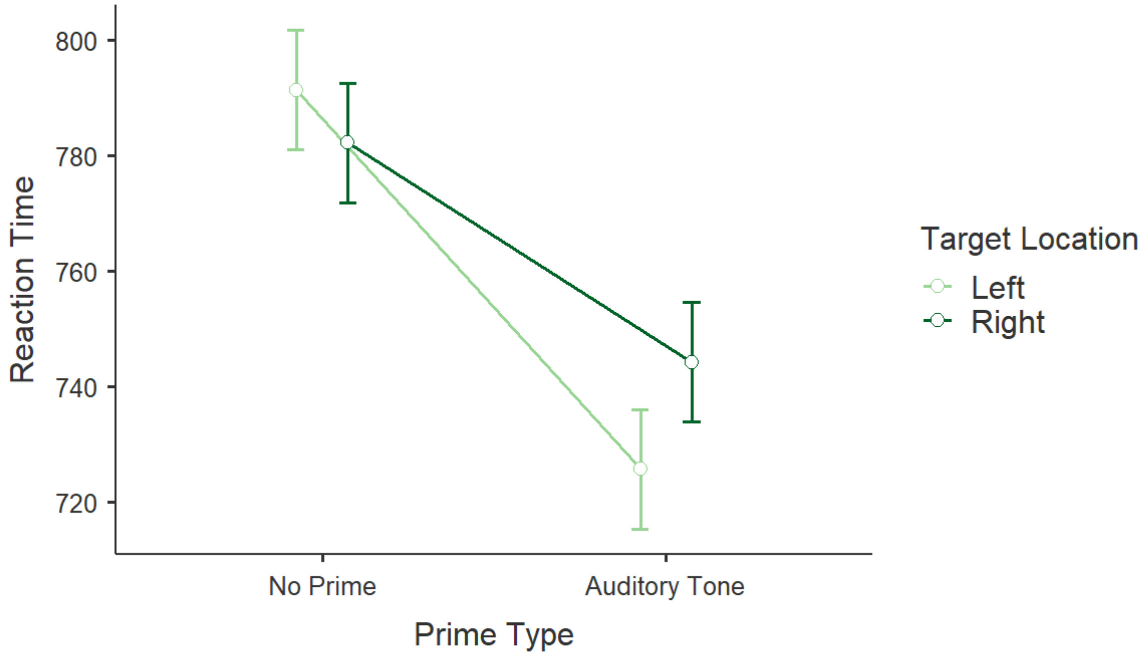

Figure 3. Mean response time (in milliseconds) as a function of primes without semantic content, and target location. Error bars represent the standard error from the mean.

Finally, we provide a supplementary analysis to investigate whether response times with the *q* key (responded with the left index finger) and response times with the *p* key (responded with the right index finger) were significantly different. This analysis overrules the possibility that the above-mentioned cueing effects are driven by the handedness of our participants. A paired samples t-test revealed that reaction time was not different when responded with the left and right hands, t (48) = 1.279, p = .207.

Eye-Tracking Data

We excluded trials in which the observer's gaze at fixation could not be verified to be within 1° of visual angle or for a minimum of 1000 ms (1.1% across all trial fixations). Fixations under 80 ms were excluded as were trials in which the tracker lost eye position (0.8%). Eye movement data concerning one participant was not included in the analyses due to software issues in the recording session. Eye movement was recorded from target onset.

Average Velocity of Saccades

In the previous analyses we have confirmed that audiovisual primes impaired responding relative to unimodal visual primes. To assess to which extent visual search was affected by audiovisual bimodal primes versus unimodal visual primes (H4), without prejudice to the emergence of congruency effect (H1), we started by analyzing the average velocity of all saccades in a trial. Average saccade velocity was computed as degrees of visual angle per second, thus higher values mean faster saccades. In other words, it is the average distance travelled by the eye in a given amplitude per second.

To this end, we start by reporting the analysis for prime types carrying semantic content in a 2 (prime type: the time-related words vs. time-related words + auditory tone) x 3 (word category: past vs. neutral vs. future) x 2 (target location: left vs. right) repeated measures ANOVA. A main effect of prime type, F (1, 47) = 65.201, p < .001, η_p^2 = .58, and of target location, F (1, 47) = 5.469, p = .024, η_p^2 = .10 were obtained. Replicating what was observed in identification latencies, written word-primes presented alone (M = 106.41, SE = 1.45) generated overall faster saccades than when these were simultaneously presented with the auditory tone (M = 97.43, SE = 1.42), which again contradicts our prediction (H4). Visual search velocity was also mildly facilitated in trials where targets were presented on the right target stream (M = 103.72, SE = 1.53) versus the left (M = 100.12, SE = 1.53).

Consistent to what we had observed in response time, an interaction of word category x target location was observed, F (2, 94) = 9.808, p < .001, η_p^2 = .17. Saccades were significantly faster in trials combining future-related words and targets on the right (M = 104.60, SE = 1.59) than targets on the left (M = 99.04, SE = 1.69; p = .002) (Fig. 4). These are the words which imply a directionality that overlaps with the rightward bias induced by scanning routines. This difference in saccade velocity was not observed following past-related words across left targets (M = 102.38, SE = 1.67) and right targets (M = 101.59, SE = 1.49; p = .654). This means that a congruency effect (H1) has emerged significantly only following future-related words. The third-order interaction did not significantly affect saccade velocity, F (2, 94) = .291, p > .748.

Finally, the primes without semantic content, that is, the absence of primes and the auditory tone conditions were compared in a 2 (prime type: no prime vs. auditory tone) x 2 (target location: left vs. right). Again, and as predicted (H3), a clear main effect of prime type was obtained, F (1, 47) = 58.717, p < .001, η_p^2 = .56. Trials with the auditory tone (M = 113.09, SE = 1.68) gave rise to substantially faster visual search, observed in the form of higher average saccade velocity, than trials without prime presentation (M = 101.53, SE = 1.29) (Fig. 5). The remaining effects were not statistically significant (all p's > .220).

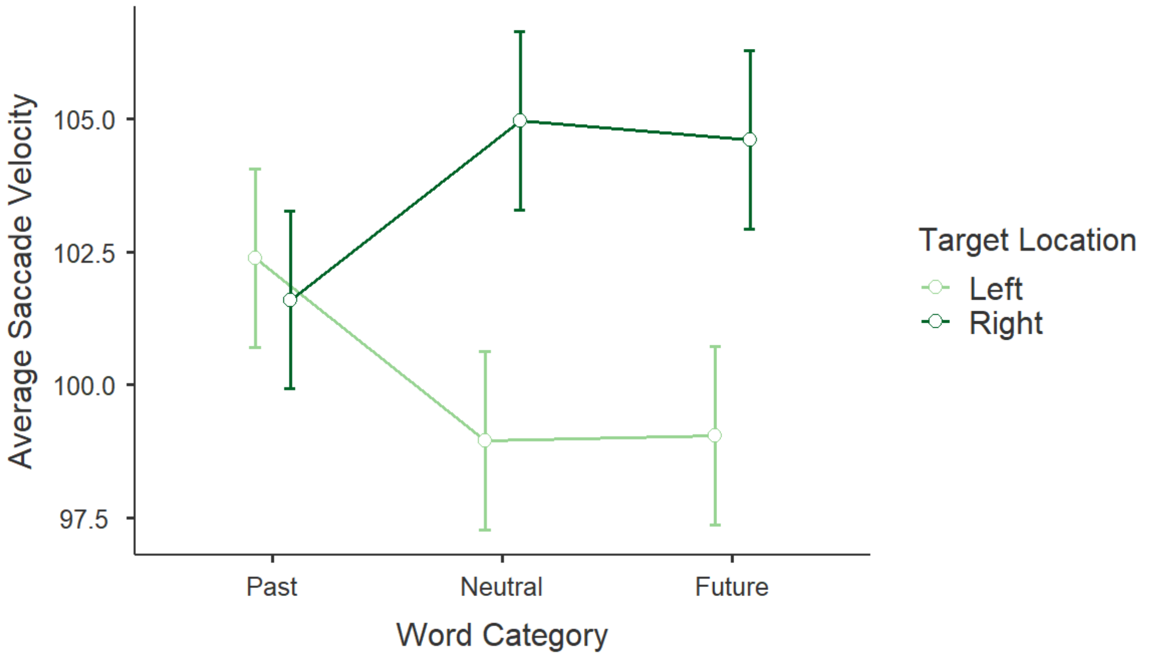

Figure 4. Average saccade velocity (degrees of visual angle per second) as a function of primes with semantic content, and target location. Error bars represent the standard error from the mean.

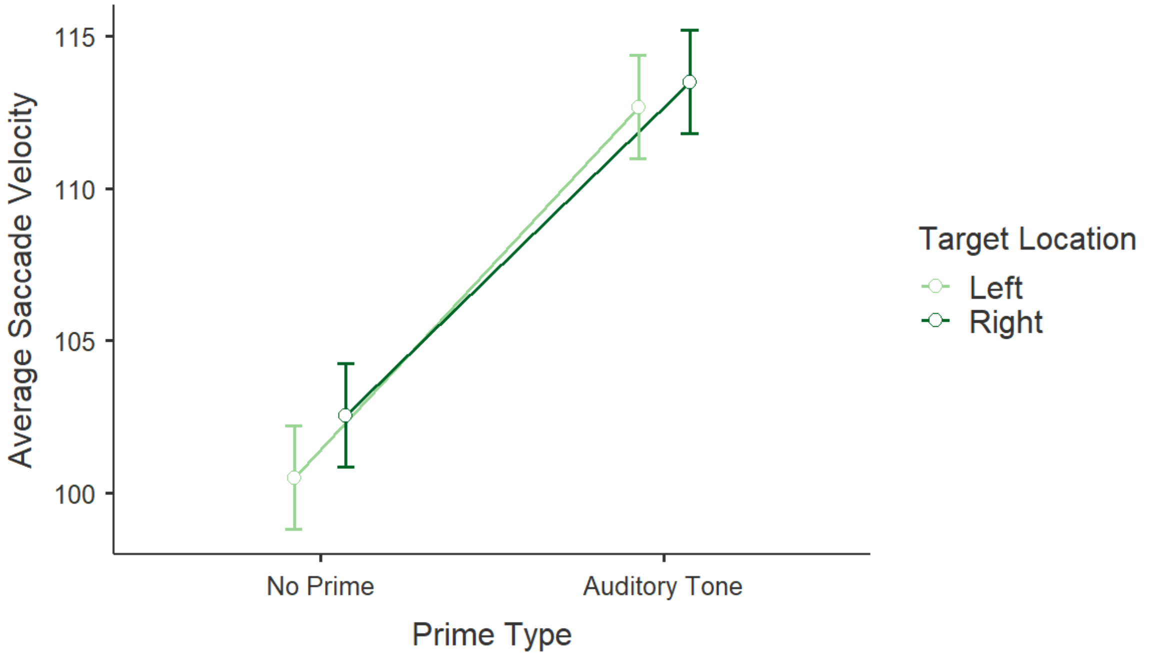

Figure 5. Average saccade velocity (degrees of visual angle per second) as a function of primes without semantic content, and target location. Error bars represent the standard error from the mean.

Direction of the First Saccade

We analyzed the percentage of first saccades made in each trial to the left and right sides of space as a function of the prime type and category of the time-related words. For obvious reasons, the latter factor was included only for the analysis of primes with semantic meaning. By analyzing the direction to which the first saccade was launched we were able to test whether the word primes triggered attention towards their implied direction (H1), validating the results obtained for the previous reported measures. We only report the percentage of saccades made to the right side of space (right saccade = 1), since reporting both percentages would be redundant.

The interesting comparison lies in the primes carrying semantic content (time-related words; time-related words + auditory tone). We obtained a clear main effect of word category, F (2, 94) = 22.121, p < .001, η_p^2 = .32 (Fig. 6). Irrespective of the prime type, future-related words triggered significantly more initial saccades to the right side of space (M = 57.98%, SE = 1.47%) compared to past-related (M = 46.63%, SE = 1.35*;* p < .001) or neutral words (M = 49.06%, SE = 1.59%; p < .001). Thus, we can conclude that the initial gaze movement of the participants seems to have responded to the informational content of the word prime as we predicted (H1), therefore attesting that time-related words can serve as attention-orienting primes. The interaction of word category and saccade direction did not yield significant differences in the percentage of right saccades generated, F (2, 94) = .034, p = 967.

Finally, the percentage of saccades towards the right side of space, and evidently to the left as well, was virtually the same following primes without semantic content (no prime; auditory tone), F (1, 47) = .165, p = .687, η_p^2 = .003. Roughly half of the first saccades were made to the right following the trials without prime (M = 50.08%, SE = 4.9%), and the same applies for the trials with the auditory tone as a prime (M = 50.37%, SE = 4.7%). These primes do not carry any informational content thus they are not able to induce expectations on target location.

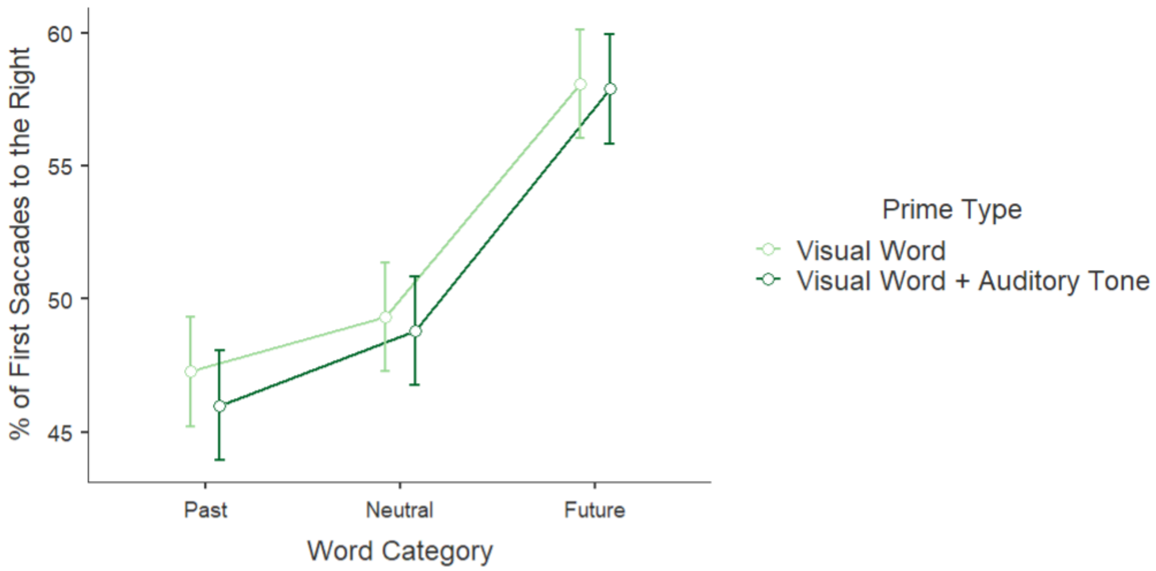

Figure 4. Mean percentage of first saccades in each trial to the right hemifield as a function of prime type, and time-related word cue category. Error bars represent the standard error from the mean.

First Fixation Onset

After having established that the word primes induce the expected orientation of attention, we further tested whether there was a right-sided asymmetry in oculomotor movement derived from scanning habits (H2) and further facilitated by bimodal stimuli (H4). To this end, we analyzed the average time elapsed until the first fixation in each trial landed on the left and right AOI's as a function of the prime type and word category. For primes without semantic content (no prime; auditory tone), the time to first fixation was analyzed across left and right AOI's.

We obtained a main effect of both prime type, F (1, 47) = 24.457, $p < .001$, $\eta_p^2 = .34$, and word category, F (2, 94) = 8.644, $p < .001$, $\eta_p^2 = .16$. Although the third-order interaction did not reveal the effect of prime type on fixation latencies (see below), first fixations following the visual words alone did occur earlier (M = 211.16, SE = 4.76), that is reached the AOI's earlier in the trial, than those following bimodal primes of word primes + auditory tone (M = 227.75, SE = 5.23). This is in line with the previous results but contrary to our prediction (H4). Rightward oriented words, those future-related, generated earlier first fixations (M = 209.28, SE = 4.39) than past-related (M = 222.24, SE = 5.48; $p = .013$), and neutral words (M = 226.95, SE = 6.08; $p < .001$). Past and neutral terms did not produce different times to first fixation ($p = .922$). This evidence reinforces that words with underlying rightward connotation do facilitate gaze movement, more so than words sharing the same category (i.e., time) but implying the opposite directionality (past-related) (H2).

A second-order interaction effect of word category x AOI emerged, F (2, 94) = 11.925, p < .001, η_p^2 = .20 (Fig. 7). As hypothesized (H1) and replicating the previous analyses, first fixations were facilitated when landing in the AOI congruent with the direction implied by the word prime. Thus, first fixations following past related words generated earlier fixations on the left AOI (M = 212.21, SE = 7.10) compared to the right AOI (M = 232.26, SE = 7.36; p = .039). In contrast, words pertaining to the future launched shorter first fixations to the right AOI (M = 192.36, SE = 4.56) than to the left AOI (M = 226, SE = 6.63; p < .001). Time taken to first fixation following neutral words did not vary across left (M = 225.46, SE = 7.27) and right AOI's (M = 228.45, SE = 7.91; p = .744). To check for our claim of asymmetrical attentional performance favoring right space (H2), we ran a direct comparison between both congruency conditions. That is, we directly compared the time to first fixation between past-related words – left AOI and future-related words – right AOI, for both prime types. We confirmed that first fixations were significantly shorter following rightward than leftward prime-target pairs. This is true for when words were presented alone, t (47) = 2.273, p = .028, and concurrently with the auditory event, t (47) = 2.356, p = .023.

The third-order interaction was not statistically significant, F (2, 94) = .145, p = .865, hence the uni- or bimodality of the primes did not interact with the remaining factors to affect the time to first fixation.

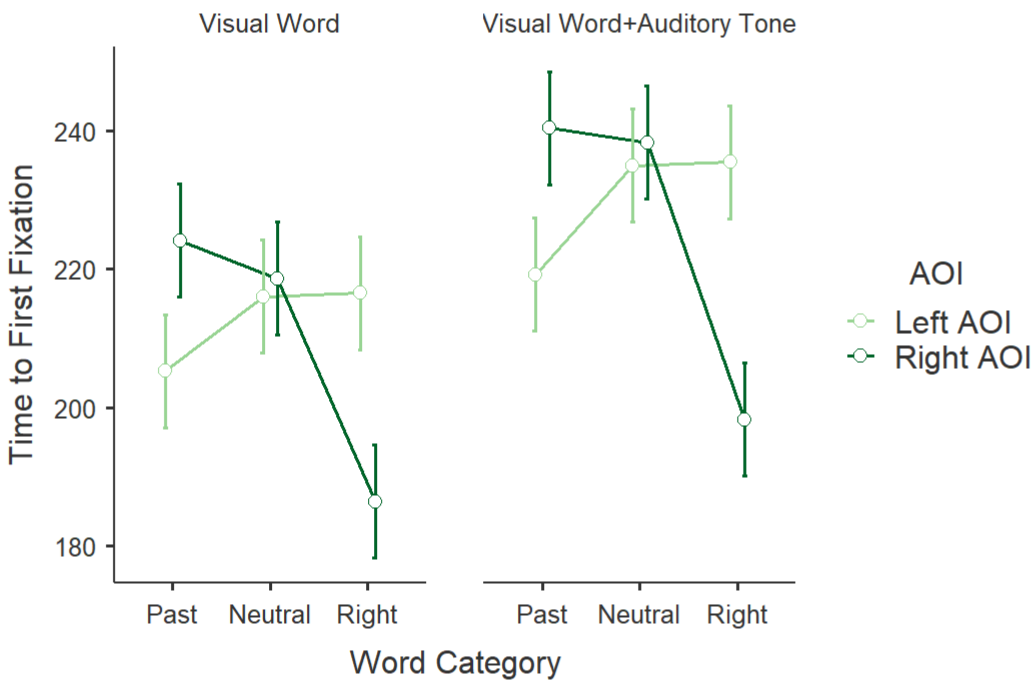

Figure 5. Average time to first fixation (in milliseconds) as a function of primes with semantic content, time-related word category, and AOI location. Error bars represent the standard error from the mean.

The comparison between the primes without semantic content (no prime, auditory tone) revealed a main effect of prime type, F (1, 47) = 13.257, p = .001, η_p^2 = .22. Supporting what was observed in the reaction time and gaze measures, the auditory tone gave rise to faster first fixations landing on the AOI's (M = 199.63, SE = 5.91) than the absence of prime (M = 218.17, SE = 5.29) (Fig. 8). The remaining effects were not statistically significant (all p's > .279).

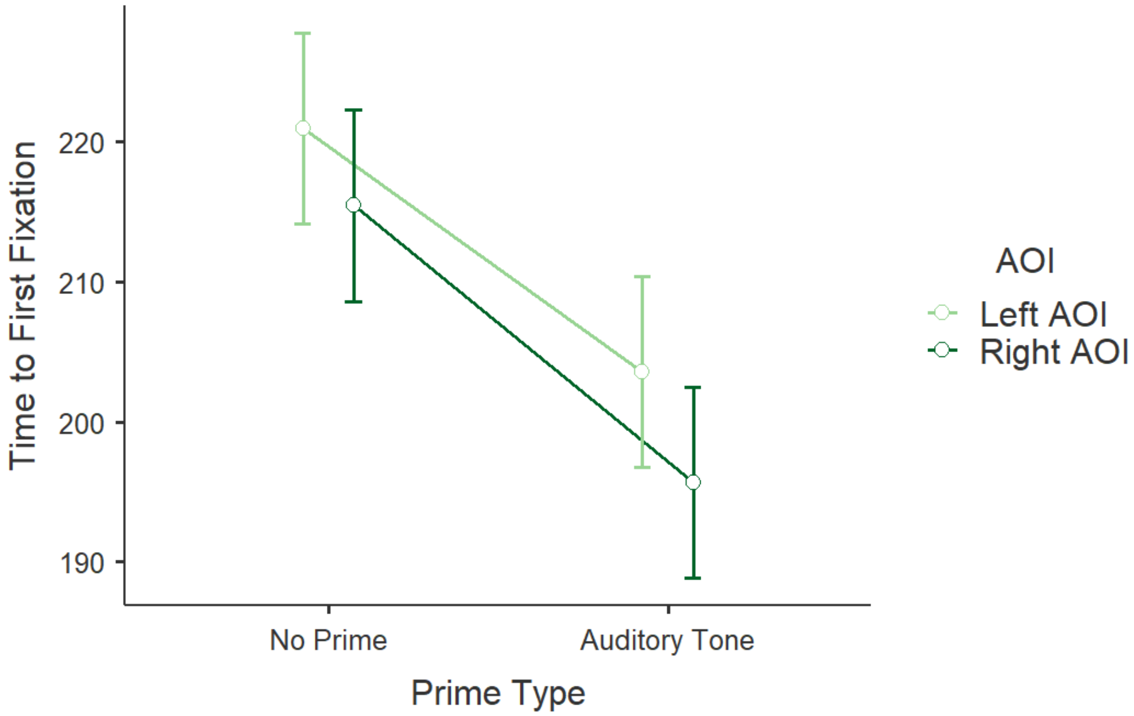

Figure 6. Average time to first fixation (in milliseconds) as a function of primes without semantic content, and AOI location. Error bars represent the standard error from the mean.

Correlation Analysis

A final correlation analysis was performed to investigate the relationship between response time, average velocity of saccades, and time to first fixation. The variables were mean centered because they had different units of measure. We observed a significant positive correlation between response time and time to first fixation (r (6098) = .032, p = .011), such that when the time participants take to land the first fixation on either interest area increases so does the time taken to identify the target. An additionally significant negative correlation was obtained between average velocity of saccades and time to first fixation, (r (6098) = -.030, p = .020). This indicates that the higher the velocity of gaze movement, the shorter the delay of the first fixation in landing on one of the interest areas. The correlation between response time and average saccade velocity was not significant (r (6098) = -.017, p = .174), although the negative correlation suggests that larger response times are associated with lower saccade velocities.

Discussion

The aim of the present study was to compare the attentional and motor effects elicited by unimodal and bimodal primes. Specifically, we hypothesized that a noninformative auditory event co-occurring with a temporal visual word suffices to increase the salience of the visual prime and consequently to enhance visual search over the visual word presented alone. In unimodal visual trials, future-related words preferentially biased attention and facilitated performance on the right hemifield due to asymmetrical routines of reading and writing. In unimodal auditory trials, the tone boosted visual search and identification of the lateralized targets. However, our results indicate that bimodal primes were not more advantageous in capturing participants' attention than the unimodal primes.

Retrospective and prospective word primes have successfully directed attention toward their implied location, be it left or right. This was revealed by shorter response latencies, faster saccade velocity, higher percentage of first saccades, and shorter time to first fixation on the congruent locations. The proposition that people make use of horizontal properties of space when processing temporal language is not new (Boroditsky et al., 2011; Fuhrman and Boroditsky, 2010; Núñez and Cooperrider, 2013; Weger and Pratt, 2008). An entirely different question is whether the time-space convergence translates into benefits for visuospatial orienting. Previous research showing that activation of past- and future-referent cues prime behavioral responses to left and right space seems to support this hypothesis (Lakens et al., 2011; Ouellet et al., 2010a; Santiago et al., 2007; Torralbo et al., 2006). Although motor outputs resulting from cueing tasks are often taken as a signal for attention allocation, they may not necessarily substantiate that attention has been deployed. Our results go one step further than prior reports by replicating the time-space overlap in motor performance while tracking participants' eye movements. The three collected measures of gaze movement systematically showed that the meaning of the temporal words was truly embodied by participants because it affected their visual attention. The fact that word category (past, future) has generated earlier first fixations on congruent areas of interest (left, right) irrespective of whether they contained the target is an indicator that participants gazed spontaneously as a response to the word prime. This suggests that, together with the first saccade direction which was congruent with the words' implied spatial information, participants gaze movement responded to the content of the primes. This spatial activation occurred despite participants being informed that the words were unrelated to target location, and thus attending to their meaning would not necessarily ensure correct target identification.

In addition, the proposed motor rightward asymmetry was also observed. The habitualized left-to-right eye trajectory appears to have promoted (marginally) faster right-sided target identification following prospective words in the condition of unimodal visual words. The significant imbalance in responding between congruent prime-target pairs on time taken to land the first fixation (a behavior that precedes motor responses) further attests that attention is not homogenously distributed but follows a preferential pattern - otherwise no differences between congruencies would have emerged. These results suggest that the precedence of the rightward scanning direction must be due, at least in part, to habitualized regularities brought upon by the convention for text direction (Bergen and Lau, 2012; Bettinsoli et al., 2019; Bulf et al., 2017; Flath et al., 2019). In fact, by acknowledging that universal genetic proclivities for a left anchoring of attention exist (Brooks et al., 2014), the right-sided advantage observed with time words in unimodal trials (which counters leftward biological predispositions) shows that reading and writing regularities must exert some form of attention control. This asymmetric spatial performance between prospective and retrospective terms is a novel contribution. It is important to note that these words are a) not overlearned (relative to terms such as 'left' and 'right', Hommel et al., 2001) and b) derived from an abstract concept (i.e. time) lacking concrete sensory-motor basis. Distinct tasks have shown that the reading and writing direction of one's native language preferentially maps human motion (Maass et al., 2009; Maass and Russo, 2003; Suitner and Maass, 2016) and by extension many other abstract concepts (e.g., politics, Farias et al., 2016; time, Lakens et al., 2011; number line, Zebian, 2005). This study is the first to show an imbalance in true attentional performance which favors prime-target combinations aligned with script direction.

Our main prediction was that the concurrent presentation of visual and auditory primes would produce an additive effect on the unidirectional spatial asymmetry described above. We expected bimodal primes, relative to their unimodal counterpart, to speed up visual search (Ngo & Spence, 2010; Van der Burg et al., 2008) and produce benefits for rightward target detection. Our results revealed the opposite. Bimodal audiovisual primes (versus unimodal visual primes) seemed to have hampered performance in response times as well as in saccade velocity and time taken to first fixation. The unimodal visual condition was substantially more efficient in grabbing attention compared to the audiovisual condition. A very different result can be seen in unimodal conditions of what we labelled as 'primes without semantic content'. When presented in isolation, the auditory tone gave rise to faster responses than trials absent of prime stimuli. It is important to note that the auditory event contained no information as to the targets' impending location. While participants could not extract any information nor rely on top-down strategies on both unimodal conditions lacking semantic content, they have performed far better in trials presenting a single tone, than in trials without a prime. Likely, exposure to the auditory event created a sense of general alertness (Coull and Nobre, 1998). The alerting signal led participants to mobilize attentional resources to the forthcoming target screen. The recruitment of these resources might have benefited the encoding of target information (Matthias et al., 2010), although no relation between tone and target timing or location could be established. Therefore, the auditory tone triggered two simultaneous processes: an alertness one that boosted motor performance, and an attentional preparedness one, that enhanced perceptual processing of targets (Correa et al., 2004; Kusnir et al., 2011).

Although we expected the same phenomena to manifest in bimodal cueing conditions, namely that the auditory tone paired with the temporal word would foster performance, we observed otherwise. Several explanations may be put forward. First, one should always consider that, in general, the visual modality takes precedence over the auditory modality (see Bertelson and De Gelder, 2004 for a review). However, if the preferred modality in our task were vision, then it would have had dominated bimodal cues and attenuated processing in the non-dominant modality, audition. If this were the case, no costs should have been observed in bimodal primes and we would have obtained the same effects across bimodal (auditory + visual) and unimodal primes (visual). Second, the bimodal stimuli in this study were employed as cues, rather than targets as in other studies demonstrating enhanced visual perception with audiovisual stimuli (Dalton and Spence, 2007; Frassinetti et al., 2002; Van der Burg et al., 2008). This means that in our study, auditory and visual events preceded target onset. Therefore, the pop-out effect that the co-occurring single tone could have induced on target discrimination was potentially invalidated.

The prime candidate explanation for the impairment in cueing effects with bimodal primes is that the co-occurring auditory tone acted as a distractor, preventing the semantic processing of the words to take place. An alternative explanation may be that the auditory tone did increase the salience of the word primes (or the fixation cross in trials without words) and the participants' focus on them. Consequently, this could delay attention to be released to the target screen, which would result in slower responses (Robinson and Sloutsky, 2010). In our view, this hypothesis is less likely because if time words were made salient, then we should have observed identification of targets on the left and right space congruent with the words' spatial information in bimodal trials.

Projective word cues such as ours impose the activation of a complex frame of reference (the retrieval of the spatial properties associated with time) (Gibson and Kingstone, 2006). The visual and semantic processing was likely interrupted by the introduction of another, albeit semantically non-competing, conjoint stimulus. This would explain why effects on the two conditions containing the auditory tone rendered opposite results: while performance was enhanced for the auditory tone alone, it was impaired when presented synchronously with the word prime, failing to recruit the necessary attentional resources. Arguably, it is also possible that audiovisual cues might benefit from slight desynchronization of its auditory and visual components in order to capture attention more efficiently (Spence and Driver, 1999). By delaying the auditory event by about 55 ms relative to the onset of the visual event, both signals would arrive synchronously at the superior colliculus. This would increase the likelihood for multisensory integration (see Spence and Santangelo, 2009 for a review). Several studies have reported enhancement in multisensory over unisensory settings (Talsma et al., 2010) particularly when modalities provide complementary information (e.g., a voice and a moving mouth Mcgurk and Macdonald, 1976; visual and auditory apparent motion streams, Soto-Faraco et al., 2002). In contrast, the introduced auditory tone was inherently nonspatial and did not provide any supplementary information to decode the target location. Thus, what might have impeded the attentional cueing effects was precisely the nonspatial feature of the auditory tone we deemed advantageous because it represented no conflicting content. It is likely that multisensory integration was not achieved because the visual and auditory properties of the stimulus were not bound into a single coherent percept (Oruc et al., 2008; Talsma and Woldorff, 2005). Hence, multiple senses did not support each other to produce an enhanced, concerted response above that evoked by the single unimodal elements (Stein and Stanford, 2008). The goal of multisensory integration is to gather information across the senses that is relevant for the self to effectively deal with the surroundings. If integration of information belonging to the same object fails, then one modality can compromise processing in the second modality (Robinson et al., 2018; Shams et al., 2002; Sloutsky and Napolitano, 2003).

It is important to note that the asymmetric performance that favored target detection on the right following unimodal future primes was observed in a sample of participants who read from left-to-right. Although there is previous research confirming that the mapping of time onto space is reversed in leftward speaking communities (Fuhrman and Boroditsky, 2010; Ouellet et al., 2010b), future research would benefit from testing the proposed asymmetry in the representation of time concepts in participants that read from right-to-left.

These findings reveal a broader picture in terms of what contributes to the triggering of visuospatial attention. They confirm that temporal language orients attention, but not equally: prospective word primes have benefits because they activate motoric and attentional processes similar to those instilled by scanning habits. The co-occurrence of an auditory, inherently nonspatial, tone (but not its single presentation) undermines motor and visual output, impairing cueing effects. The results find support in other studies that failed to report attention capturing advantages for bimodal over unimodal cueing (Santangelo et al., 2006; Ward et al., 1998) and therefore constitute an important advance to the multisensory cueing literature.

References

Afsari, Z., Keshava, A., Ossandón, J.P., König, P., 2018. Interindividual differences among native right-to-left readers and native left-to-right readers during free viewing task. Vis. cogn. 26, 430–441.

Alvarado, J.C., Vaughan, J.W., Stanford, T.R., Stein, B.E., 2007. Multisensory versus unisensory integration: Contrasting modes in the superior colliculus. J. Neurophysiol. 97, 3193–3205.

Anderson, S.F., Kelley, K., Maxwell, S.E., 2017. Sample-size planning for more accurate statistical power: A method adjusting sample effect sizes for publication bias and uncertainty. Psychol. Sci. 28, 1547–1562.

Barnhart, W.R., Rivera, S., Robinson, C.W., 2018. Different patterns of modality dominance across development. Acta Psychol. (Amst). 182, 154–165.

Bergen, B.K., Lau, T.T.C., 2012. Writing direction affects how people map space onto time. Front. Psychol. 3, 109.

Bertelson, P., De Gelder, B., 2004. The psychology of multimodal perception. In: Charles, S., Driver, J. (Eds.), Crossmodal Space and Crossmodal Attention. Oxford University Press, Oxford, England, pp. 141–179.

Bettinsoli, M.L., Maass, A., Suitner, C., 2019. The first, the least and the last: Spatial asymmetries in memory and their relation to script trajectory. Mem. Cogn. 47, 229–239.

Boroditsky, L., Fuhrman, O., McCormick, K., 2011. Do English and Mandarin speakers think about time differently? Cognition 118, 123–129.

Boroditsky, L., Gaby, A., 2010. Remembrances of times east: Absolute spatial representations of time in an australian aboriginal community. Psychol. Sci. 21, 1635–1639.

Brooks, J.L., Sala, S. Della, Darling, S., 2014. Representational pseudoneglect: A review. Neuropsychol. Rev. 24, 148–165.

Bulf, H., De Hevia, M.D., Gariboldi, V., Cassia, V.M., 2017. Infants learn better from left to right: A directional bias in infants' sequence learning. Sci. Rep. 7.

Butler, S.H., Harvey, M., 2006. Perceptual biases in chimeric face processing: Eye-movement patterns cannot explain it all. Brain Res. 1124, 96–99.

Chahboun, S., Flumini, A., Pérez González, C., McManus, I.C., Santiago, J., 2017. Reading and writing direction effects on the aesthetic appreciation of photographs. Laterality Asymmetries Body, Brain Cogn. 22, 313–339.

Chokron, S., De Agostini, M., 2000. Reading habits influence aesthetic preference. Cogn. Brain Res. 10, 45–49.

Correa, Á., Lupiáñez, J., Milliken, B., Tudela, P., 2004. Endogenous temporal orienting of attention in detection and discrimination tasks. Percept. Psychophys. 66, 264–278.

Coull, J.T., Nobre, A.C., 1998. Where and when to pay attention: The neural systems for directing attention to spatial locations and to time intervals as revealed by both PET and fMRI. J. Neurosci. 18, 7426–7435.

Dalton, P., Spence, C., 2007. Attentional capture in serial audiovisual search tasks. Percept. Psychophys. 69, 422–438.

Driver, J., Spence, C., 1998. Cross–modal links in spatial attention. Philos. Trans. R. Soc. London. Ser. B Biol. Sci. 353, 1319–1331.

Farias, A.R., Garrido, M. V., Semin, G.R., 2016. Embodiment of abstract categories in space. . . grounding or mere compatibility effects? The case of politics. Acta Psychol. (Amst). 166, 49–53.

Fernandez-Duque, D., Posner, M.I., 1997. Relating the mechanisms of orienting and alerting. Neuropsychologia 35, 477–486.

Flath, M.E., Smith, A.K., Elias, L.J., 2019. Cultural differences in lateral biases on aesthetic judgments: The effect of native reading direction. Cult. Brain 7, 57–66.

Frassinetti, F., Bolognini, N., Làdavas, E., 2002. Enhancement of visual perception by crossmodal visuo-auditory interaction. Exp. Brain Res. 147, 332–343.

Fuhrman, O., Boroditsky, L., 2010. Cross-cultural differences in mental representations of time: Evidence from an implicit nonlinguistic task. Cogn. Sci. 34, 1430–51.

Gibson, B.S., Kingstone, A., 2006. Visual attention and the semantics of space: beyond central and peripheral cues. Psychol. Sci. 17, 622–7.

Hernandez, M.D., Wang, Y., Sheng, H., Kalliny, M., Minor, M., 2017. Escaping the corner of death? An eye-tracking study of reading direction influence on attention and memory. J. Consum. Mark. 34, 1–10.

Ho, C., Santangelo, V., Spence, C., 2009. Multisensory warning signals: When spatial correspondence matters. Exp. Brain Res. 195, 261–272.

Ho, C., Spence, C., 2005. Assessing the effectiveness of various auditory cues in capturing a driver's visual attention. J. Exp. Psychol. Appl. 11, 157–174.

Hommel, B., Pratt, J., Colzato, L., Godijn, R., 2001. Symbolic control of visual attention. Psychol. Sci. 12, 360–5.

Jewell, G., McCourt, M.E., 2000. Pseudoneglect: A review and meta-analysis of performance factors in line bisection tasks. Neuropsychologia 38, 93–110.

Kermani, M., Verghese, A., Vidyasagar, T.R., 2018. Attentional asymmetry between visual hemifields is related to habitual direction of reading and its implications for debate on cause and effects of dyslexia. Dyslexia 24, 33–43.

Kusnir, F., Chica, A.B., Mitsumasu, M.A., Bartolomeo, P., 2011. Phasic auditory alerting improves visual conscious perception. Conscious. Cogn. 20, 1201–1210.

Lai, V., Boroditsky, L., 2013. The immediate and chronic influence of spatio-temporal metaphors on the mental representations of time in English, Mandarin, and Mandarin-English speakers. Front. Psychol.

Lakens, D., Semin, G.R., Garrido, M. V., 2011. The sound of time: Cross-modal convergence in the spatial structuring of time. Conscious. Cogn. 20, 437–43.

Laurienti, P.J., Perrault, T.J., Stanford, T.R., Wallace, M.T., Stein, B.E., 2005. On the use of superadditivity as a metric for characterizing multisensory integration in functional neuroimaging studies. In: Experimental Brain Research. Exp Brain Res, pp. 289–297.

Leys, C., Ley, C., Klein, O., Bernard, P., Licata, L., 2013. Detecting outliers: Do not use standard deviation around the mean, use absolute deviation around the median. J. Exp. Soc. Psychol. 49, 764–766.

Maass, A., Pagani, D., Berta, E., 2007. How beautiful is the goal and how violent is the fistfight? Spatial bias in the interpretation of human behavior. Soc. Cogn. 25, 833–852.

Maass, A., Russo, A., 2003. Directional bias in the mental representation of spatial events: Nature or culture? Psychol. Sci. 14, 296–301.

Maass, A., Suitner, C., Favaretto, X., Cignacchi, M., 2009. Groups in space: Stereotypes and the spatial agency bias. J. Exp. Soc. Psychol. 45, 496–504.

Majid, A., Gaby, A., Boroditsky, L., 2013. Time in terms of space. Front. Psychol. 4, 554.

Matthias, E., Bublak, P., Müller, H.J., Schneider, W.X., Krummenacher, J., Finke, K., 2010. The influence of alertness on spatial and nonspatial components of visual attention. J. Exp. Psychol. Hum. Percept. Perform. 36, 38–56.

Mcgurk, H., Macdonald, J., 1976. Hearing lips and seeing voices. Nature 264, 746–748.

Mills, M., Smith, K.B., Hibbing, J.R., Dodd, M.D., 2015. Obama cares about visuo-spatial attention: Perception of political figures moves attention and determines gaze direction. Behav. Brain Res. 278, 221–225.

Ngo, M.K., Pierce, R.S., Spence, C., 2012. Using multisensory cues to facilitate air traffic management. Hum. Factors 54, 1093–103.

Ngo, M.K., Spence, C., 2010. Auditory, tactile, and multisensory cues facilitate search for dynamic visual stimuli. Attention, Perception, Psychophys. 72, 1654–1665.

Núñez, R., Cooperrider, K., 2013. The tangle of space and time in human cognition. Trends Cogn. Sci. 17, 220–229.

Núñez, R., Cooperrider, K., Doan, D., Wassmann, J., 2012. Contours of time: Topographic construals of past, present, and future in the Yupno valley of Papua New Guinea. Cognition 124, 25–35.

Oruc, I., Sinnett, S., Bischof, W.F., Soto-Faraco, S., Lock, K., Kingstone, A., 2008. The effect of attention on the illusory capture of motion in bimodal stimuli. Brain Res. 1242, 200–208.

Ossandón, J.P., Onat, S., König, P., 2014. Spatial biases in viewing behavior. J. Vis. 14, 1–26.

Ouellet, M., Santiago, J., Funes, M.J., Lupiáñez, J., 2010a. Thinking about the future moves attention to the right. J. Exp. Psychol. Hum. Percept. Perform. 36, 17–24.

Ouellet, M., Santiago, J., Israeli, Z., Gabay, S., 2010b. Is the future the right time? Exp. Psychol. 57, 308–314.

Rashidi-Ranjbar, N., Goudarzvand, M., Jahangiri, S., Brugger, P., Loetscher, T., 2014. No horizontal numerical mapping in a culture with mixed-reading habits. Front. Hum. Neurosci. 8, 1–5.

Robinson, C.W., Moore, R.L., Crook, T.A., 2018. Bimodal presentation speeds up auditory processing and slows down visual processing. Front. Psychol. 9, 1–10.

Robinson, C.W., Sloutsky, V.M., 2010. Development of cross-modal processing. Wiley

Interdiscip. Rev. Cogn. Sci. 1, 135–141.

Santangelo, V., Spence, C., 2008. Is the exogenous orienting of spatial attention truly automatic? Evidence from unimodal and multisensory studies. Conscious. Cogn. 17, 989–1015.

Santangelo, V., Van Der Lubbe, R.H.J., Belardinelli, M.O., Postma, A., 2006. Spatial attention triggered by unimodal, crossmodal, and bimodal exogenous cues: A comparison of reflexive orienting mechanisms. Exp. Brain Res. 173, 40–48.

Santiago, J., Lupiáñez, J., Pérez, E., Funes, M.J., 2007. Time (also) flies from left to right. Psychon. Bull. Rev. 14, 512–516.

Santiago, J., Román, A., Ouellet, M., Rodríguez, N., Pérez-Azor, P., 2010. In hindsight, life flows from left to right. Psychol. Res. 74, 59–70.

Selcon, S.J., Taylor, R.M., McKenna, F.P., 1995. Integrating multiple information sources: Using redundancy in the design of warnings. Ergonomics 38, 2362–2370.

Shaki, S., Fischer, M.H., Petrusic, W.M., 2009. Reading habits for both words and numbers contribute to the SNARC effect. Psychon. Bull. Rev. 16, 328–331.

Shams, L., Kamitani, Y., Shimojo, S., 2002. Visual illusion induced by sound. In: Cognitive Brain Research. Elsevier, pp. 147–152.

Sloutsky, V.M., Napolitano, A.C., 2003. Is a picture worth a thousand words? Preference for auditory modality in young children. Child Dev. 74, 822–833.

Smith, A.K., Duerksen, K.N., Gutwin, C., Elias, L.J., 2020. Lateral biases in aesthetic and spatial location judgments: differences between tasks and native reading directions. Laterality Asymmetries Brain, Behav. Cogn. 25, 5–21.

Soto-Faraco, S., Lyons, J., Gazzaniga, M., Spence, C., Kingstone, A., 2002. The ventriloquist in motion: Illusory capture of dynamic information across sensory modalities. In: Cognitive Brain Research. Elsevier, pp. 139–146.

Spence, C., Driver, J., 1997. Audiovisual links in exogenous covert spatial orienting. Percept. Psychophys. 59, 1–22.

Spence, C., Driver, J., 1999. A new approach to the design of multimodal warning signals. Eng. Psychol. Cogn. Ergon. 4, 455–461.

Spence, C., Parise, C., Chen, Y.C., 2011. The Colavita visual dominance effect. In: McDonald, J.J., Green, J.J., Störmer, V., Hillyard, S.A. (Eds.), The Neural Bases of Multisensory Processes. CRC Press/Taylor & Francis, pp. 529–556.

Spence, C., Santangelo, V., 2009. Capturing spatial attention with multisensory cues: A review. Hear. Res. 258, 134–142.

Stein, B.E., Stanford, T.R., 2008. Multisensory integration: Current issues from the perspective of the single neuron. Nat. Rev. Neurosci. 9, 255–266.

Suitner, C., Maass, A., 2016. Spatial agency bias: Representing people in space. Adv. Exp. Soc. Psychol. 53, 245–301.

Suitner, C., Maass, A., Ronconi, L., 2017. From spatial to social asymmetry: Spontaneous and conditioned associations of gender and space. Psychol. Women Q. 41, 46–64.

Talsma, D., Senkowski, D., Soto-Faraco, S., Woldorff, M.G., 2010. The multifaceted interplay between attention and multisensory integration. Trends Cogn. Sci.

Talsma, D., Woldorff, M.G., 2005. Selective attention and multisensory integration: Multiple phases of effects on the evoked brain activity. J. Cogn. Neurosci. 17, 1098–1114.

Teder-Sälejärvi, W.A., McDonald, J.J., Di Russo, F., Hillyard, S.A., 2002. An analysis of audio-visual crossmodal integration by means of event-related potential (ERP) recordings. In: Cognitive Brain Research. Elsevier, pp. 106–114.

Torralbo, A., Santiago, J., Lupiáñez, J., 2006. Flexible conceptual projection of time onto spatial frames of reference. Cogn. Sci. 30, 745–57.

Tversky, B., Kugelmass, S., Winter, A., 1991. Cross-cultural and developmental trends in graphic productions. Cogn. Psychol. 23, 515–557.

Van der Burg, E., Olivers, C.N.L., Bronkhorst, A.W., Theeuwes, J., 2008. Pip and pop: Nonspatial auditory signals improve spatial visual search. J. Exp. Psychol. Hum. Percept. Perform. 34, 1053–1065.

von Sobbe, L., Scheifele, E., Maienborn, C., Ulrich, R., 2019. The space-time congruency effect: A meta-analysis. Cogn. Sci. 43, e12709.

Vroomen, J., De Gelder, B., 2000. Sound enhances visual perception: Cross-modal effects of auditory organization on vision. J. Exp. Psychol. Hum. Percept. Perform. 26, 1583–1590.

Wallace, M.T., Meredith, M.A., Stein, B.E., 1998. Multisensory integration in the superior colliculus of the alert cat. J. Neurophysiol. 80, 1006–1010.

Ward, L.M., 1994. Supramodal and modality-specific mechanisms for stimulus-driven shifts of auditory and visual attention. Can. J. Exp. Psychol. 48, 242–259.

Ward, L.M., McDonald, J.J., Golestani, N., 1998. Cross-modal control of attention shifts. In: Wright, R.D. (Ed.), Vancouver Studies in Cognitive Science. Oxford University Press, pp. 232–268.

Weger, U.W., Pratt, J., 2008. Time flies like an arrow: Space-time compatibility effects suggest the use of a mental timeline. Psychon. Bull. Rev. 15, 426–430.

Welch, R.B., Warren, D.H., 1986. Intersensory interactions. In: Boff, K.R., Kaufman, L., Thomas, J.P. (Eds.), Handbook of Perception and Performance: Sensory Processes and Perception. Wiley, New York, NY, pp. 25–36.

Zebian, S., 2005. Linkages between number concepts, spatial thinking, and directionality of writing: The SNARC effect and the REVERSE SNARC effect in English and Arabic monoliterates, biliterates, and illiterate Arabic speakers. J. Cogn. Cult. 5, 165–190.

Chapter VII. General Discussion

This dissertation has attempted to demonstrate the pervasive impact of the culturally transmitted ascription of agency onto space. Early exposure to formal activities of reading and writing is believed to be at the source of a preferred spatialization of human movement. However, it is but through extended practice that cultures instill directional attentional regularities that bias core areas of human functioning.

The experience of moving in space parallels that engaged by the undertaking of reading and writing activities whereby the reader establishes a natural correlation between the movement of eye and hand progressing in space and the occurrence of novel information. These iterations universally experienced by all are what motivate the linear representation of human agency as well as other abstract concepts devoid of sensorimotor input (e.g., time, politics). This representation becomes apparent in most languages through metaphorical spatial terminology that articulates some form of movement. The recursive movement-space transactions establish enduring links with the coordinates of left-right, which eventually become part of our linguistic ecology. Metaphors typify ideomotor action because the processing of metaphorical terms known to anchor on the horizontal dimension (e.g., time-related) recruits the motoric modality (e.g., facilitates eye and hand movements).

The understanding of elusive concepts like time and politics is permeable to orthographic or ecological variations but has the physical experience of space as the common denominator. One of these cultural variations is script direction which we have shown to weigh heavily on habit formation. Culturally determined orthographic directionality carries strong sensory-based interdependencies with space and modulates basic representational, attentional, and cognitive processes. For this reason, this hallmark of language was selected as the underlying conduit to the studies in this dissertation.

The set of studies this dissertation puts together was designed under the assumption that cognition is not encapsulated within the self but interlocked with (not apart from) sensorimotor experience and finely tuned to the immediate reality. The current research systematically demonstrated that performance is influenced by entrenched orthographic regularities. As such, the symbolic representation of stimuli our tasks entailed, whichever form they took, is not immune to contextual pressures. A fine exemple of modulation by context is the study with Arabic-speaking communities which revealed consistent but reversed results to those observed in the Portuguese-speaking community. The perceptual simulation that was carried out by participants when recovering these cultural horizontal asymmetries was observed in contexts where movement was not required (influencing social inferences, chapter II) and in contexts where motor and eye movement were necessary for task completion (influencing lateralized detection decisions, chapters III-VI). In any case, the connection between the results reported in this set of studies can be seen in that the generic property that communicates conventionalized orthographic movements was internalized by participants across tasks, cues, and modalities. This movement continuum is the broad unifying principle that binds the findings of this dissertation together.

The general discussion is organized into six parts as follows. In the first three, I review the specific goals that drove the empirical research and address how the findings can be generalized by discussing their significance for a broader embodied account of human agency. The general discussion of the empirical research (chapters II-VI) has been broken down to tackle the distinct types of stimuli used: Attention-driving properties of faces, attention-driving properties of verbal information, and attention-driving properties of integrated modalities. The fourth part addresses the limitations of this body of work and puts forth experimental approaches overcoming these shortcomings. The fifth part outlines the practical implications of this work and advances ecological ways in which this research could be capitalized by field practitioners. Finally, I conclude with the final remarks of this dissertation.

Attention-driving properties of faces

Social Inferences

The first study of this dissertation was designed to investigate how the dominant direction of reading and writing (i.e., left-to-right) shapes agency perceptions and by extension the assignment of other agency-related traits. Social inferences on fourteen trait dimensions were made on a set of target faces in front-, left-, and right-oriented perspectives. Ratings were reduced to two dimensions of what we termed ‘power’ and ‘social-warmth’. The spatial agency bias-derived expectation was that faces averted rightward, known to communicate agentic qualities, would give rise to higher endorsement of the traits clustered on the power dimension. The results indicate that right-oriented faces (relative to front- and left-facing profiles), that are aligned with the horizontal left-right continuum that grounds agency, structure the overall attribution of social traits on both dimensions. However, ratings of rightward faces were substantially more pronounced for power-like traits compared to communal-like ones.

On a broader first look, these findings replicate a variety of analogous dimensional stereotype content or face evaluation models that converge in demonstrating that the variance in trait judgments of self, persons, and even groups can be captured accurately enough by two fundamental social-cognitive dimensions (agency and communion, Abele, 2003; morality and competence, Abele & Wojciszke, 2014; warmth and competence, Fiske et al., 2002; trustworthiness and dominance, Oosterhof & Todorov, 2008; other-profitability and self-profitability, Peeters, 1992; Phalet & Poppe, 1997; affiliation and dominance, Wiggins, 1979). Although referred to by different names and emerging from different research traditions, there is a considerable semantic and functional overlap to these conceptual opposites. Similarly, the results of our study show that a dual-factor solution represented by an agentic/power dimension and a communal/warmth dimension is well suited to summarize social attributes from faces.

As it would be expected, the weight such components carried for the big picture of social inferencing did not follow a similar-sized distribution. The interesting twist is revealed by the exploratory analysis, further corroborated by a distinct sample, showing that the variance explained by the power dimension surpassed by much that explained by the social-warmth dimension. This result counters prior reports that have shown a higher preponderance of valence-related over dominance-related traits in accounting for the variability in face evaluation (Oosterhof & Todorov, 2008). One could argue that the frequency of trait use may have affected rating scores. The present data do not allow such extended conclusions. However, it is unlikely that the traits encompassing the power dimension are more frequently used in common discourse, and therefore more salient and accessible to the social judges. Terms like “agency”, “dominance”, or “strength” are surely less intuitive to the perceiver than terms like “attractiveness”, “familiarity”, and “emotion” that hold more stable meanings across cultures (Ybarra et al., 2008). Encounters with the linguistic terms that constitute our primary component are rarer, context-dependent, and often circumscribed to describing persons in work/institutional settings. On the other hand, the communal, social-warmth traits are likely to enter the perceiver’s reality more often because their use is abundant in everyday speech to denote qualities of loved ones and strangers alike.

One critical difference in our study is that the face evaluations were not restricted to frontal angles, like in the work of Oosterhof and Todorov (2008). We tested the attribution of social inferences in a heterogeneous face set that included critical right-facing profiles known to encourage agency ratings (Suitner et al., 2017). Agency-ratings are themselves correlated to other agentic qualities clustering on the power dimension (Abele et al., 2008; Hitlin & Elder, 2007). It therefore looks like the rightward faces assumed a greater importance on the overall face set and the agentic properties they conveyed were critical for social judgment. In a relative way, this speaks to the preeminent role that right profiles have in driving overall face evaluation as well as their potential to trump ‘softer’ communal inferences. Furthermore, the variance in social inferences explained by the power cluster is seen for the global face set (i.e., multiple face perspectives) which really represents an enhanced ecological setting, since in everyday life we do not always come across people facing front.

An additional consideration goes to the context, which evaluators may have inferred to be connecting all target faces. The face models were students sharing appearance and demographics, certainly close in age, and rather homogeneous. It would not be difficult for the attentive perceiver to deduce that they were part of a university sample. Although no information on the models was provided, we may have inadvertently primed a specific evaluative context that made competence and industriousness (i.e., agency-like) attributes more relevant. In this scenario, inferences would be mostly dominated by the power dimension and eclipsed on the social-warmth one (Oosterhof & Todorov, 2008). There is numerous research attesting that relation-oriented traits are more critical in person perception than those derived from the agency dimension (Wojciszke et al., 1998; Ybarra et al., 2001). In the first instance, the decision to qualify someone as harmful or beneficial to the self carries more weight in affective responses than the judgment of the person's ability to implement these intentions (Wojciszke & Abele, 2008). However, if by seeing the models, perceivers inferred an academic context in which agentic qualities are not only appreciated but desirable, then the prevalence of social-warmth traits may have been overridden by the power dimension.

We observed that both power and social-warmth dimensions were affected by the rightward perspective of faces, although to very different degrees. Power ratings were substantially more marked for right profiles than social-warmth ratings. In fact, all eight individual trait items clustered on the power dimension were significantly more affected by the rightward faces than the other two face orientations. As for social-warmth attributions, only three items comprising this scale were higher for right-facing faces relative to left-facing faces. Our data indicate that the influence of right face direction cuts across both dimensions (with diverging magnitude but converging directionality) but prior research has suggested opposites of left-right to best capture the attribution of communion versus agency, respectively. The leading argument is that communion lacks a concrete motoric anchor while agency is grounded by physical movement. Therefore, any spatial bias arising from communality traits emerges in opposition to agency and is an epiphenomenon of the latter rather than a bias in its own right. That is perhaps why leftward oriented vectors like arrows are deemed more appropriate to symbolize communion versus rightward signals that are preferred to convey agency (Suitner et al., 2017). Our results indicated otherwise since ratings on both dimensions were driven by right faces. Likely, the overall rightward preference may be explained by the ease of eye movements participants made while inspecting script-coherent visual information (i.e., rightward photos), which has been suggested to increase processing fluency, and in turn, amplify evaluations (Chae & Hoegg, 2013; Lee & Aaker, 2004). Because people hold spatially-specific expectations, the scrutiny of visuals in general and any resulting inferences benefit from the match between graphic layout and the familiar trajectory of script that produces an overall feeling of fit (Monahan & Romero, 2020).

An interesting study by Sutherland and colleagues (2017) permits interesting parallels to our data. The authors examined whether emotional expression and head orientation affected reports of trustworthiness, dominance, and attractiveness to faces. Their analysis revealed that faces oriented right (both three-quarter and full profile) received significantly higher scores overall across all emotion and head orientation conditions. Because the authors were not theoretically interested in exploring differences between left and right viewpoints, data for this factor was collapsed precluding further conclusions on how face directionality drives judgments of trustworthiness, dominance, and attractiveness. Nevertheless, it underscores that there is something distinctive about the rightward directionality that seems to magnify face perception in general. We observed a similar phenomenon in our data, but we argue that rightward preference is not uniformly distributed across trait judgments. It is rendered more salient for the range of social attributes expressing properties akin to agency and that ground on the horizontal axis. The rightward direction of faces had already been reported to promote stereotypical agency, even when face direction is an irrelevant task feature (Suitner et al., 2017). The novelty of our study lies in the remaining social traits loading on the power component which, to the best of our knowledge, had not yet been shown to associate with the rightward direction. The terms used, it should be noted, are remarkably distinct in their semantics. It is an underlying left-right property of movement that ties the grounding of all these categories. We show that the orthographic movement serves as an umbrella-principle for several distinct concepts that are dissimilar in nature yet equally susceptible to priming by the manipulation of face perspective. This finding alone offers a new and more integrative framework to the spatial agency bias account.

The research in chapter II has demonstrated that (rightward) faces are an effective medium to communicate agency and its correlated attributes. In lacking clear emotional cues broadcasting a person’s intentions, face orientation seems to be determinant in driving social inferences. Further, it underscores that the dominant orthographic direction not only shapes the interpretation of actual human movement (Maass et al., 2007) but has also less obvious consequences for person evaluations. The attribution of social inferences and interpretations of actions are, after all, affected in similar ways. Having established that rightward faces carry agentic qualities and hence left-right movement, it is only logical to surmise that they are suitable stimuli to test the effect of asymmetrical scanning habits on other fundamental cognitive processes, namely in the orientation of attention.

Attention and Detection

The set of two studies reported in chapter III examined a) the potential of laterally averted faces as attention orienting cues, and b) how script-coherent habits can enforce a privileged pattern of visual exploration that modulates attention, a fundamental feature of human cognition presumed to operate relatively independent from culture. Participants were asked to make speeded discriminations of lateralized target letters preceded by right- and left-looking face stimuli in a spatial cueing task. Results were consistent with the rightward asymmetry hypothesis. Rightward face profiles produced a right-sided advantage in motor and attentional performance over the remaining face perspectives, an outcome that indicates a nonuniform distribution of visual attention. All else being equal, one would expect attention (and detection) to be arbitrarily distributed across hemifields following either face direction. Results from chapter III directly contradict the account for symmetrical performance as a product of congruent cue-target arrangements. In a 'Western' linguistic community, rightward stimuli gained additional significance by activating a similar motoric scanning to that acquired through habitualized practices of reading-writing (Suitner & Maass, 2016). The same scanning could not be observed for leftward faces because these go against the expectancies of learned eye-movement trajectory.

We have observed that face perspectives produced congruent detection effects across measures, although differentiated between face orientations. Extensive prior research has demonstrated that people are particularly good at discerning eye gaze in human faces because gaze conveys biologically relevant information and is preponderant in social communication (Allison et al., 2000; Hoffman & Haxby, 2000). When we see a person looking in a particular direction our attention shifts to the same location, which is assumed to be of interest (Frischen et al., 2007; Langton & Bruce, 1999). Therefore, gaze direction alone offers a crucial cue for attention orientation. What we hypothesized, and observed, is that congruent gaze and face direction, particularly one that overlaps with the habitual movement of writing/reading activities and communicates agency, produces an asymmetrical orientation of attention.

Humphreys (2013) pointed out that the statistical learning of the frequency of actions and events in everyday real-world environments creates attentional spatial biases to directional stimuli. An example of such iterative behavior capable of shaping attention is precisely the exposure to the dominant script direction and other cultural coherent layouts. From a statistical learning account, rightward faces demand more frequently a response by a preferred eye-movement trajectory (e.g., left-to-right), and create a sensitivity to co-occurrence that may amplify differences in orientation effects on visual search (Humphreys, 2013; Humphreys & Riddoch, 2007). The results from both studies reported in chapter III seem to corroborate this thesis. Right orientations, which mimic the movements evoked in daily directional activities, gave rise to a systematic rightward bias in attention scanning observed in motor and visual responses.

The fact that attentional performance across hemifields was not homogeneous warrants further scrutiny. Participants prioritized rightward faces over other directionalities. This was manifested in an asymmetric performance between congruent cue-target combinations throughout. For example, the first fixation launched in each trial landed earlier in the right target region after a rightward face was presented, substantially more so than on the left target region following a leftward looking face. Evidently, this accelerated gaze movement to the right resulted in further advantageous discrimination of targets on the same location. This data advance prior conclusions showing that manipulated head and gaze stimulus drive attention in the horizontal axis (Friesen & Kingstone, 1998; Frischen et al., 2007). Further, it shows that regularities of reading and writing impose an additional layer to the attention generated by faces; one that favors left-to-right movement and ultimately produces benefits on the right space (Morikawa & McBeath, 1992). The conclusion is supported by the fact that performance on the left was consistently diminished. This is because the right-to-left trajectory that the scanning of leftward faces induces is both counterintuitive and more costly for the eye of the habitualized left-to-right perceiver. The visual system takes advantage of environmental regularities to predict the occurrence of upcoming information in locations consistent with momentum with greater ease to the perceiver (Spalek & Hammad, 2004).

Nevertheless, presumed biological proclivities in the anchoring of spatial attention should not be left out of the equation. The term ‘pseudoneglect’ (Jewell & McCourt, 2000) is now used more loosely to describe the general tendency humans have for preferentially anchoring attention on the left. The phenomenon is reported in tasks engaging visual, motor, and haptic modalities (Bradshaw et al., 1987; Levander et al., 1993; Varnava et al., 2002). The predisposition is largely credited to brain asymmetries in the allocation of spatial attention, namely the contralateral attentional orienting produced by the right hemisphere that enhances the left perceptual field (Reuter-Lorenz et al., 1990). However, there is evidence that the scanning strategies adopted by participants influence decisions. For example, when ask to bisect a horizontal line on its midpoint, subjects tend to err left when scanning was initiated from the left side and err right in the right-scanning condition (Chokron et al., 1998). Biological tendencies are therefore passive to modulation by a number of external and individual variables (Jewell & McCourt, 2000), one of which is habitual reading style (Chokron & Imbert, 1993). At the very least, this indicates that hemispheric factors are not preponderant in the distribution of attention. These conclusions conform with those of other authors (Abed, 1991; Afsari et al., 2018; Eviatar, 1997; Rashidi-Ranjbar et al., 2014) and contest universal left hemispace attentional preferences (Ossandón et al., 2014). Lateral biases in the visual attention system should be construed as deriving from an interactive account of genetic and cultural asymmetries, which predominance varies as a function of task, stimuli, modality, and individual idiosyncrasies (Chokron & De Agostini, 2000; Rinaldi et al., 2014). While we cannot dismiss that biological factors may be at play, our results demonstrate that the leftward preference can be modulated by cultural factors. The observed right-sided advantage indicates that ‘Western’ directional habits are established to an extent that suffices to counteract, or at least lessen, genetically inscribed attentional inclinations. If biological asymmetries were the sole driving force of attention, or at least the most impactful one, we would not have observed amplified cueing effects following right faces but following left faces which are consistent with the biological leftward tendency.

The broad contribution of the three studies reported with face cues (chapters II-III) is to be seen in that static stimuli associated with the direction used to represent movement (i.e., rightward faces) are powerful enough to engage visuomotor systems and induce concrete eye-gaze movements, just like moving stimuli do (Maass et al., 2007). These cues successfully redescribed simulations of motion (i.e., eye movements) registered during the perceiver’s interactions with the world (i.e., motion carried out during reading and writing activities and its further generalizations) (Barsalou, 2008). Notably, the dynamic property these faces convey is not explicit (like when seeing an image of an athlete in the posture of throwing a ball, Freyd, 1987; or when reading the word “kick”, Hauk et al., 2004). For attention to be biased, perceivers must recover past associations between agency and space initially created by formal scholarly activities and extended by a lifetime of visuospatial practice. The effectiveness of right face cues in endorsing agentic-related social judgments (chapter II) and evoking actual biased motion (chapter III) denotes that agency-space co-occurrence has become internalized. This bias was systematically observed in judgment and attention, across two fundamentally distinct tasks that required different problem-solving strategies.

Additionally, an attention bias that is rooted in linguistic dependencies was achieved using fundamentally non-linguistic cues. The observed link between agency and horizontal space was signaled by 'language-free' materials. This element renders the contribute of these studies that much more relevant. Participants activated spatial information in contexts in which they are not required to produce or process language. This means that agency-space associations are habitualized to such a degree that linguistic cues are no longer needed to produce the spatial bias. Although the results with face cues provided compelling evidence that an agentic spatial schema is transmitted by language script, we conducted additional studies to ascertain that the spatial bias is culturally shaped, and convergent across other types of cues (e.g., verbal stimuli).

Attention-driving properties of verbal information

Time

In three distinct but interrelated studies using the same spatial cueing task, lateral face stimuli were replaced by words about abstract categories of time (chapter IV) and politics (chapter V), known to indicate semantically congruent horizontal locations. These categories share the spatial mapping of agency and the expectation was that they would be likewise susceptible to the same visuomotor biases. Two studies employed cues with temporal connotation. The first study was conducted with words in the visual and auditory modalities in a left-to-right speaking population (Portuguese) and the second was conducted with visual words in a right-to-left speaking population (Arabic). In chapter V, we reported one study that aimed to extend the findings with temporal words to the less examined, and further removed from space, category of politics.

Across studies, 'right-oriented' words (conservatism-related for politics, future-related for time) observed a privileged processing that translated into faster visual attention and target discriminations on the right hemifield, relative to the left word cue – left target counterpart. This effect was observed across visual and auditory modalities. The Arabic-speaking participants nicely mirrored the performance of Western participants. The same advantage for terms about the future was found, but the advantage was now observed on the left space, which underscores the reverse mapping of time from right (past) to left (future). The results provide one step forward towards establishing the spatial agency bias as a cultural attention-driven mechanism that can be vehiculated, aside from pictorial, by verbal information.

I will first discuss the results in terms of what they signify to a general account on the representation of abstract concepts. In a broad stance, these results can be framed in embodied cognition theories that hold concepts, however abstract, linked to sensorimotor experiential states. The studies on time and politics support that mental representation of these abstract concepts is sustained by metaphorical language, which links intangible knowledge to concrete properties of physical space (Vigliocco et al., 2014). Statistical information is implicitly extracted from the left-right associations that are formed whenever people talk and think about time and political concepts. This process culminates in the activation of action systems when called upon (e.g., horizontal eye movement), which constitute an essential aspect of language processing (Yaxley & Zwaan, 2007). Our results show that abstract words effectively elicited perceptual simulations and guided attention to their implied left-right location, in similar ways that concrete object and animal words trigger faster responding for targets appearing in the objects' canonical locations (Zwaan & Yaxley, 2003). This is in accordance with embodiment-based findings that contend that abstract and concrete concepts engage the same systems during perception and action (Connell & Lynott, 2012).

The intriguing result lies in the fact that, just like the two studies with faces (chapter III), cue words were irrelevant for successful task completion given that they did not reliably inform the observer of the upcoming target location. Still, and although there was no benefit to attending to the cues, their spatial information was activated. This finding goes against claims that embodied simulations in concept understanding are recruited only when concepts are task-relevant (Flumini & Santiago, 2013). Similarly, other authors have contended that space-time mappings in the left-right axis emerge only when tasks require temporal discrimination (Ulrich & Maienborn, 2010). In our task, participants did not have to reason about temporal language nor make explicit temporal judgments. Participants responded to lateralized ‘context-free’ targets that served as a proxy to measure spatial associations. This means that the salience of the ‘time’ category was minimized so that any emerging congruency effects could be read as a product of automatic space-time associations and the additional layer of language direction. Therefore, we add to prior literature (see Sobbe et al., 2019 for a meta-analyses) by showing that it is possible to prime time-space mappings by using temporal words that are irrelevant for accomplishing the task. These findings are well in line with Lakoff and Johnson’s (1999) proposal that “*very little of our understanding of time is purely temporal. Most of our understanding of time is a metaphorical version of our understanding of motion in space*” (p. 139).

On the other hand, it is possible to argue that had we used the same terms in different task requirements (not entailing semantic processing), embodied simulations would not have emerged. For example, in an EMG study, Niedenthal and colleagues (2009) noticed that emotion words (e.g., joyful, foul) activated facial muscles when participants were asked if the words were associated with an emotion but not when their task was to determine if words were capitalized. This indicates that motor engagement for the same stimuli is context-dependent. Indeed, there seems to be a consensus among scholars that conceptual congruency (i.e., interaction between response direction and concept reference) in time-related judgments is context-sensitive (Lakens et al., 2011; Santiago et al., 2010, 2012; Torralbo et al., 2006).

Aside from the contribution to the literature on the horizontal grounding of time described above, the added-value of these studies is how two potential sources of bias, the spatial anchoring of words and the cultural orthographic direction, would operate together to exert a dual influence on how attention and detection is driven. Both forces induce movement in the same cultural direction but the unidirectional scanning that reading-writing activities elicit superimposes an attention-orienting asymmetry on the congruency generated by the semantic indication of words. This joint process resulted in visual asymmetries that favored spatial locations consistent with the indication of script direction.

The claim that directional cultural habits shape the spatialization of time is supported by the study with an Arabic-speaking population. All cultures organize temporal events in terms of a mental timeline (running from left/right to right/left, top to bottom, back to front) and in exceptional cases, multiple coexisting mental timelines (e.g., Boroditsky, 2011; Boroditsky et al., 2011; Boroditsky & Gaby, 2010). The activation of these frames of reference depends on the culturally salient preferences that include a combination of bodily experiences, language, gesturing, entrenched directional habits, context/task requirements, and temporal focus (Callizo-Romero et al., 2020; Casasanto & Jasmin, 2012; Pitt & Casasanto, 2019; Santiago et al., 2011). Although cultures rely on diverse spatial referents to code time, linear representations (left-right or vice versa) afford universal perceptuo-motor bases acquired early in development (Clark, 1973) and are therefore grasped more intuitively. People choose to arrange time horizontally even when they are not limited to a two-dimensional space (Fuhrman & Boroditsky, 2010). In part, left-right referents are commonly adopted because practically all alphabetic writing systems are horizontally laid out and scripts become a transversal and practical way to communicate meaning.

Despite all cultural intricacies, Arabic participants mirrored the behavioral pattern of responses observed with the 'Western' population, reflecting that people rely heavily on spatial representations consistent with the course of habitual temporal reasoning (i.e., right-to-left). Past was mapped on the right and future on the left. Earlier research reached similar conclusions (Fuhrman & Boroditsky, 2010; Ouellet, Santiago, Israeli, et al., 2010; Tversky et al., 1991) but these differ substantially in one crucial point. Critically, we demonstrated that the spatial bias induced by the semantic indication of time words is supplemented by a habitualized feature of language that exerts an asymmetry on the primary spatial mappings. This collaborative effort of both attention-orienting forces on the mapping of time is the novel contribution of this research. In this sense, the two studies with time word cues (chapter IV) advance prior research by demonstrating that a) time representation is consistent with the readily available concrete sensorimotor experience of reading and writing (i.e., movement in space), and b) spatial horizontal referents are entrenched to such an extent that they are activated even in the absence of overt temporal reasoning.

Finally, although no conclusive assertions can be made in what respects attention allocation, the Arabic study provides useful points of comparison. The congruency effect alone does not necessarily indicate that the allocation of attention was reversed. What shows that attention mimicked language direction is the leftward bias, notably opposite to the rightward one observed for Portuguese participants. Performance was facilitated following the same words that conveyed a script-coherent directionality (i.e., future-related), but now on the left hemispace. Despite the lack of an objective measure of attention, but based on the asymmetric performance observed, it's possible to conclude that attention was deployed in a script consistent manner. Having recorded Portuguese participants' allocation of attention, one can argue that the same – or better said, the opposite - has occurred for the Arabic sample given that eyes and attention move together in space, and consequently, so does behavior (Fischer, 1998).

Politics

We attempted to generalize the results of the studies with time words by replacing these terms for politically laden words. The domain of politics was examined in the Portuguese population. Across behavioral and gaze movements, as well as auditory and visual modalities, we observed the proposed rightward asymmetry. This result is consistent with the movement direction performed when reading and writing.

The findings with political cues may be difficult to reconcile with the Conceptual Metaphor Theory approach (Lakoff & Johnson, 1980) because it holds that abstract concepts detached from sensorial experience are represented via readily available concrete physical properties. However, abstract concepts are diverse, and some hold closer links to the environment than others. It is the interplay between sociality and language that shapes how these concepts are differentially grounded. Political metaphorical language, unlike metaphors of time, has its origins in relatively recent happenings. It arises from seating arrangements in the 18th century French National Assembly where members in support of the King sat to the right and those opposing his policies to the left. This apparent incidental historical connection placed political values on the left-right continuum. It follows that politically-charged terms hold less statistical frequency by emerging less often in colloquial discourse than those of time. While time is constant, politics are dynamic and not impervious to change. Political words may quickly shift between 'conservatism' or 'socialism' categories, gaining a whole other significance. Nevertheless, it is evident that political spatial language has gained currency and is shared today by political enthusiasts and lay people alike.

It is extremely unlikely that the understanding of politics lies (at least exclusively) on the chronic concomitant experience of political language and physical coordinates of left-right. Also, there is no systematicity in graphic depictions of political symbols and candidates' placement in media that contributes to the left-right spatialization of politics (Casasanto, 2013). Rather, mental political metaphors are maintained by linguistic repetitions converging in a shared linguistic ecology that preserves the connection between political ideology and spatial referents. Because the link to physical space is tenuous at best, it is remarkable that political words gave rise to comparable attentional cueing effects to those generated by time words. These findings are important because they expand the link between conceptual and physical space to the scarcely examined domain of politics. The fact that physical spatial references in politics have long been abandoned indicates that political geography is now maintained through language, and hence liable to the directional properties associated with it. Moreover, politics are not coupled with spatial representations in artifacts of everyday life. For example, we are abundantly exposed to the progression of time in calendars, graphs, and flowcharts. These spatial conventions are likely to validate embodied routines and ultimately enable visuomotor performance. We observed that words from a category rather remote from space (but deep-seated in language) not only are sufficiently strong to induce shifts of attention congruent with their semantic connotation but are also permeable to be biased by language direction.

In addition, we show that it is possible to prime political space without overt bodily manipulations. Previous studies on the mapping of politics have conducted posture and balance manipulation. In this scenario, participants are inevitably made aware of their own body positioning which triggers unconscious proprioceptive feedback that can affect further behavior (e.g., orienting people to the left/right, Dijkstra et al., 2012; Oppenheimer & Trail, 2010). In this case, the body itself serves as a cue for action. In our studies, single conceptual political words presented in the absence of any integrable context (like when a full sentence is provided, Stanfield & Zwaan, 2001) were sufficient to evoke an associated spatial imagery that created a preparedness for action. We observed that perceptual simulation (and further motor execution) can be carried out via linguistic stimuli and without actual engagement of the motor system (e.g., running on a treadmill, pedaling on a bike, leaning towards a side).

Word stimuli that are inherently nonspatial and in which people are less proficient (unlike the words 'left'/'right', Hommel et al., 2001) have influenced gaze direction to the hemifield consistent with a) the political ideology of the cue (congruency), and b) the preferred trajectory instilled by reading habits (asymmetry). Our eye-gaze results fit with Mills and colleagues' (2015) who demonstrated that perceiving well-known political figures shifted attention in line with the politicians' ideology. The manual results also converge with Farias and colleagues (2013, 2016) by ascertaining that politics are charted on the horizontal plane. Newly, our findings bring together gaze and behavioral measures to show that political words with rightward connotation underlie a property of movement and hence enjoy privileged processing. Furthermore, and as observed with time-related words, biased political mappings showed redundancy in vision and audition given that performance was not differentiated between sensory modalities.

A final word goes to the nature of the linguistic stimuli employed. Time- and politically-relevant words are spatially represented along a continuum and not just dichotomously categorized in left-right coordinates. Evidently, words are graded differently in people's mental imagery because certain words weigh heavier and are more impactful than others. For example, politics is rarely as simple as groups of three (left, moderate/center, right) (Beard, 2003). People typically endorse policies from one side of the political spectrum more so than the other, but it is not unusual that the same person holds conflicting political opinions. A person can experience the full gamut of political positioning which conditions how political knowledge is perceived and stored. Further, political categories always carry affective connotations. It is very difficult to find neutral vocabulary in political terminology because political words are marked heavily in valence. Even words less charged (i.e., what we termed 'neutral' in our study) may easily shift between 'left' and 'right' categories in the representational system of the perceiver. In addition, the same word can carry inter-individual subjectivity because it can potentiate different connotations depending on who uses it (for example, the word 'radical' can be applied to both poles of the spectrum).

In this matter, there are stark differences between politics and time. Time words are relatively immune to fluctuations in meaning and valence (e.g., there is no a priori reason to presume that the word 'before' is more/less positive than the word 'after'). Although cultures can modulate the importance paid to the past and future, the spatial significance of time (and its deriving terms) remains somewhat unchanged and is grasped collectively in similar ways. Time encompasses an organic property that politics lack, perhaps because its mapping can be traced back to our own bodies (time is laid out in body-relative space) and is extractable from world experience (time produces unidirectional change) (Boroditsky & Ramscar, 2002). Consequently, words imported to talk about time appear to be universal across languages and cultures (Boroditsky, 2011). Those employed in politics are extremely sensitive to individual and cultural variations. Because cautionary notes have been raised that words reflect different spatial-semantic gradations (Farias et al., 2013; Lakens et al., 2011), our studies controlled for the variance introduced by the words meaning. The effect of words did not override the posited effect of language direction in visuomotor performance. Evidently, there are no purely neutral words, as Bakhtin (1981) reminds us: "*All words have the 'taste' of a profession, a genre, a tendency, a party, a particular work, a particular person, a generation, an age group, the day and hour. Each word tastes of the context and contexts in which it has lived its socially charged life (…)"* (p. 293). However, we employed words in isolation in a speeded decision task devised to foster attentional, not linguistic, processes. Therefore, no reflective mindset was involved (as initial gaze movement confirms). The words we termed 'neutral' in our studies assumed intermediate values between left and right anchors and were devoid of any intrinsic directionality. The 'taste of the context' in which they have arisen did not play a role in guiding attention. This tells us that these words were assessed in terms of the very basic spatial properties they elicit and were unlikely to involve any further linguistic reasoning in such a 'context-free' environment. This lends more credence to our argument that what lies at the core of spatial asymmetries is a cultural property of movement that linguistic stimuli encapsulate.

Overall, the three studies with political and time words extend the conclusions of the two studies with non-linguistic face stimuli (chapters II and III). They show that spatial language is more than a convenient form of quick reference. Together with cultural directional pressures, it meddles in how we construe temporal and political information. We extend prior studies (Hartmann et al., 2012) by showing that overt (or even apparent) action is not a necessary condition for the processing of abstract language and the emergence of the movement bias. Furthermore, we show that interacting with writing systems explains a great deal of how literate humans come to represent abstract information and create (pre-established) expectations of how movement should unfold. The study with Arabic-speaking individuals is particularly pivotal to strengthen this claim. The leftward attention bias obtained in this linguistic community (one assumably familiar with 'western' scanning routines) was not weaker than that observed for the Portuguese community (as reported in Flath et al., 2019; Friedrich & Elias, 2016). Crucially, we show that two categories accommodated by the same horizontal referent but very dissimilar in semantics observed comparable results. We conclude that politics and time share the same cultural direction of movement that ultimately biases attentional processes in a spatially-specific manner. This data recognize the combined importance of linguistic and social experience for the embodiment of human agency.

Attention-driving properties of integrated modalities

The last empirical chapter integrated three attention-orienting research fields contributing to attentional and cognitive biases. These are the semantic anchor of temporal words, the cultural scanning habits, and location-free auditory signals shown to improve visual search. These factors, while interrelated, have been addressed separately and their integration enables a more comprehensive overview of what lies behind one's inclination to attend some locations to the detriment of others. A nonspatial auditory tone and visual temporal words which we showed to drive asymmetric attention served as cues (unimodal and bimodal). For unimodal visual words, detection latencies and gaze movements revealed the expected congruency effect. Again, spatial congruency was differentiated for future-related words and targets on the right hemifield, suggesting that rightward eye and motor trajectory shape performance. The unimodal auditory tone acted as a warning signal by improving attention and facilitating detection but when synchronously presented with the visual words (bimodal cues), it hampered visual search and response times.

First, it is essential to highlight that the observed rightward asymmetry is consistent with that offered by our previous studies (chapters III-V). Past and future words have successfully driven attention to the horizontal dimension (left and right space, respectively). These groundings (Lakens et al., 2011; Ouellet, Santiago, Funes, et al., 2010; Santiago et al., 2007; Torralbo et al., 2006) were further permeable to the convention of text direction. Gaze measures were unequivocal in revealing that participants embodied a feature of movement that is culturally communicated by language script (Suitner & Maass, 2016). I will not elaborate on this argument further as it has been extensively discussed in the previous research. The spatial bias has now been observed in a wealth of distinct tasks (Carnaghi et al., 2014; Chahboun et al., 2017; Maass et al., 2007, 2009; Spalek & Hammad, 2005; Vaid et al., 2002). The studies composing this dissertation have further validated spatial asymmetries with face and word stimuli in two abstract categories (and not mere action verbs associated with a coherent direction, Richardson et al., 2003), and across two sensory modalities.

The main prediction under examination here was that the biased representation of visual temporal terms would benefit from the synchronous presentation of an auditory single tone. The rationale stemmed from research showing that auditory tones drastically decrease search times for visually coordinated objects (Van der Burg et al., 2008). The underlying assumption is that visual and auditory information are integrated into a single coherent percept, increasing target salience, and automatically drawing attention to that location. We speculated that the intensity of the rightward effect observed in the study with time words (chapter IV) would be augmented by the addition of concurrent sound stimuli (Stein et al., 1996). The idea is based on a cohort of research showing that multimodal stimulus features, relative to their unimodal features, heighten perceptual awareness and reduce search latencies (Ngo et al., 2012; Ngo & Spence, 2010; Simon & Craft, 1970; Spence & Santangelo, 2009). What is unprecedented here is testing whether the bimodal cues exponentiate the spatial bias effect.

Contrary to our expectations, and what the literature seemed to imply, there was no gain in coupling the visual words with the auditory signal. Visual and motor performance in audiovisual trials was substantially delayed compared to its unimodal visual counterpart. There is a sensible justification for such a result that we had not anticipated. Intersensory interactions are only beneficial to the perceiver insofar as they provide complementary information (Sinnett et al., 2008) or even multimodal redundancy (Selcon et al., 1995). Evidently, when two sensory modalities are competing for attentional resources, one modality is likely to trump the other (Barnhart et al., 2018; Robinson & Sloutsky, 2010). Attention is first and foremost a mechanism that serves the adaptive purpose of scouting for changes in the vicinities. Failing to carry on information from two sensory modalities, attention will prevail to that which is preponderant to the self in a given situation. In our data, it was not the case that one modality dominated the other (e.g, visual dominance is common in adult populations, Sinnett et al., 2007). The pairing of the auditory tone with the visual word did not give rise to a performance similar to that observed for the visual words alone – as would be expected if vision had acted as the dominant modality. Instead, there was a cost in the speed of discriminating visual information when bimodal cues were processed. This indicates that bimodal presentation increased the perceptual load and the task demands (Lavie, 2005), which led to processing in both modalities being equally slowed down.

We were aware of prior neurophysiological research denoting that conflicting sensory information may alter or attenuate processing on either modality (for a related discussion see Eimer & Velzen, 2002). However, we theorized that an auditory tone that is bare of context, location and is language-free, would not compromise multisensory integration but decrease mental task demands instead (Van der Burg et al., 2008). However, our task was substantially different than previous ones. First, prior research presented the target and cue simultaneously (while in our task, the bimodal cues preceded the target). This may have canceled out the ‘popping’ of the target that cues potentiate. Second, the visual event accompanying the auditory tone is typically a line segment or similar, hence not meaning-based (words), and captured in terms of basic low-level features. Finally, a visual change (a rotation in the line segment) typically occurs whenever the auditory signal was presented which yields a unified perceptual experience. In our task the target set was stationary.

These differences proved crucial in rendering any bimodal cueing effects significant. From an ecological standpoint, bimodal cues are efficient so long as they are advantageous to the impending reality of the perceiver. If one of the sensory modalities provides irrelevant (albeit spatially nonconflicting) information, this stimulus becomes ‘noise’; it nonetheless consumes processing resources but contributes nothing to a final, concerted response (Stein & Stanford, 2008). Because the auditory tone we employed had no added value to the task at hand, we conclude that it hampered the processing of the temporal visual words which entail a rather complex frame of reference (Gibson & Kingstone, 2006). Ultimately, the failure in creating a synergy between modalities precluded additive effects that lead to improved performance in multisensory settings (Talsma et al., 2010).

Moreover, although participants could not extract any spatial information from the auditory tone in both uni- and bimodal conditions, the auditory tone presented in isolation boosted visual and manual performance. The unimodal auditory condition is critical to understand the inefficacy of bimodal cues and to support the claim that the single tone disrupted the processing of the synchronous words. It rules out the hypothesis that the auditory tone had no attention-driving properties since it successfully acted as an alerting event and captured cross-modal attention. Neither is the case that the visual temporal words did not induce attention in a semantically-consistent manner (as seen in the unimodal visual condition). The likely take-home message is that the product of this particular combination of auditory tone + time words did not rise above the cueing effects evoked by their single unimodal components. We speculate that multisensory integration is only enjoyed when visual and auditory information are perceived as complementary and originating from a single coherent object (Wallace et al., 1998). It is also possible that had we presented the auditory tone immediately before the word cue, cueing effects would have emerged. In this scenario, the tone would likely enhance sensorial acquisition for the semantic information that followed (word), instead of overloading the attentional system. Nevertheless, our research does not stand alone in concluding that audiovisual cues are less effective than their unimodal counterpart in securing attention (Santangelo et al., 2006; Spence & Driver, 1997; Ward, 1994; Ward et al., 1998).

I will not discuss this contribution to detail as multimodal cueing of attention is a (sizable) research field in its own right. Aside from the relevance to the debate on multisensory integration and cross-modal attention (Koelewijn et al., 2009), this study offers important insights regarding the value of multiple modalities in testing the cultural spatial bias. Despite some inconclusive evidence, there is still a substantial body of research showing that, on occasion, responding benefits from bimodal presentation (for a review see Spence & Driver, 2012). This is most evident when sensory modalities provide supportive information (Fort et al., 2002). It would therefore be unwise to peremptorily affirm that multisensory effects cannot be achieved with co-occurring abstract information supplied in visual and auditory modalities. The current set of bimodal data does not enable such extrapolation. Yet, data from our previous studies showed that both time and political words presented visually and auditorily (separately) can bias orientation of attention. Thus, provided that multisensory cues converge, it is reasonable to assume that audiovisual abstract primes could produce an enhanced asymmetrical response above that observed in the audio and visual single priming conditions (chapters IV and V).

Imagine a setup where an image of a well-known political figure (e.g., Donald Trump) is simultaneously presented with an auditory word that falls into the politician's ideology (e.g., 'conservatism'). In this scenario, the resulting cueing effects may reveal the accumulated input of the two modalities (even if redundant, Selcon et al., 1995) to be above those evoked by the single unimodal presentation. It follows that the directional habits imposed by script would also manifest on top of these bimodal cueing effects. An alternative proposition to explore the movement bias in a multimodal setting would be to present an auditory event resembling apparent motion (a binaural sound originating from one ear channel to the other, e.g., the sound of a moving train) with a visual cue portraying abstract information that implies direction (e.g., the word 'future'). Importantly, our research with integrated modalities merged evidence from the previous empirical chapters addressing the role of sensory modalities in isolation. Its goal was to demonstrate whether incrementally complex research conditions would render similar asymmetric effects. In this sense, this research unravels (part of) the boundary conditions under which the spatial bias operates.

Limitations and Future Research

The seven studies in this dissertation have shown that an arbitrary aspect of language like the directionality of written script is not inconsequential. Instead, our evidence echoes previous research by showing that the embodied reading-writing movement cultivates lateral biases in attentional skills and visual exploration (Andrews et al., 2013; Bettinsoli et al., 2019; Chokron & Imbert, 1993; Pollatsek et al., 1981; Smith & Elias, 2013; Spalek & Hammad, 2005; Suitner & Maass, 2016), which come to affect social judgments (Maass et al., 2009; Suitner et al., 2017) and spatial imagery of abstract language (Farias et al., 2013; Fuhrman & Boroditsky, 2010; Mills et al., 2015; Santiago et al., 2010).

One crucial element to support the main tenet of this dissertation is the verification of the visuomotor asymmetries in participants from opposite writing systems. In the study with Arabic participants, we could confirm that the spatial bias in the representation of time is reversed in communities socialized into a right-to-left script. It is reassuring that a reversal was obtained from Arabic speakers who are not exclusive unidirectional readers (many have reported speaking rightward languages). This is a significant achievement because not all research has found complete reversals (Suitner & Maass, 2016). We were unable to collect attentional measures due to logistic constraints, leaving unspecified how these populations would behave as far as attentional performance goes. Of course, both the asymmetrical response times of these participants and the manual and gaze measures of the Portuguese sample warrant predictions about how Arabic-speaking subjects would behave. In any case, considering the present evidence, it would be imprudent to declare that leftward populations are biased by the direction of reading/writing to the same extent as rightward populations. For that reason, future studies should test attentional asymmetries more broadly in leftward samples and in other abstract categories aside from time. Politics, for instance, pose a good example given that this category is more permeable to cultural variations.

In the same vein, samples should be restricted to nationals of the same country to guarantee cultural homogeneity beyond language direction. We were forced to include participants from sixteen Arabic speaking countries to meet sample size requirements. On the one hand, the mirrored performance observed is robust because it derives from a rather representative leftward sample. On the other hand, different countries sharing the same language are certain to have nuances in the meaning of words and to inculcate distinct directional manifestations on their members as a function of their openness to opposite spatial layouts (Román et al., 2015). These culture-specific conventions may weigh just as heavily as language direction and can be quite resistant to change (de Sousa, 2012). Therefore, future research avenues would benefit from testing spatial asymmetries derived from reading habits in single-country samples. This would help disentangle the relative weight of culture and of hemispheric and universal invariants on agency perception, which remains an issue of debate (Chatterjee et al., 1999; Kranjec & Chatterjee, 2010; Mandal & Ambady, 2004).

Another issue that deserves additional scrutiny is the target setup employed which can be said to create confounds with stimulus-response compatibility effects (Proctor & Cho, 2006). The responses in our studies implied pressing left and right keys using the left and right hands as effectors, respectively. First, the fact that cues (either face images or words) did not have a direct connection with space and were presented centrally on the screen may, in principle, mitigate any dimensional overlap between cue and target sets (Fitts & Seeger, 1953). In addition, correct responses were determined by target location (target on the left/right) but what was measured was target discrimination (selection of p/q), which served as a proxy for the first. Target letters were counterbalanced such that targets appeared on the right/left sets with a 50:50 distribution following either stimulus directionality. Therefore, we did not increase the salience of any of the responding poles, as the spatial code of the target was uncorrelated with the required response (Umiltá & Nicoletti, 1990). To a large extent, the setup we devised circumvents problems with stimulus-response compatibility. Nevertheless, correspondence in space is a powerful source of bias that should not be overlooked (Cho & Proctor, 2003). Although having no clear left-right labels, the cues and targets we used referred participants to the same horizontal dimension. One rather simple solution to disentangle this confound would be to align the response keys vertically, instead of horizontally. Previous studies on the mapping of politics have done so and observed political grounding to be independent of the match introduced by the response codes (Farias et al., 2016). It is, however, not clear whether vertical response codes would provide the decisive answer because responses on the vertical dimension may reflect pure valence classifications (e.g., ‘up is good/bad is down’, Meier & Robinson, 2004). In sum, polarity correspondence in binary tasks like ours is difficult to escape. Future research is urged to formulate more inventive designs to avoid such confounds.

A further interesting manipulation would be to present the target sets not only along the horizontal axis but on the vertical axis as well (with the same strings horizontally laid out). By instructing participants to detect lateralized targets, we inevitably primed them to look to the left and right hemispace and rendered any asymmetries more salient. For example, it is now known that the lateral mental timeline can co-exist with vertical and sagittal representations of time, although time is predominantly mapped horizontally whenever tasks invoke a movement experience like ours (Ding et al., 2020). Nevertheless, and because alternative conceptualizations of abstract concepts can emerge from different task demands, target sets presented in the four cardinal directions could clarify what axis is primarily preferred for the spatial mapping of abstract concepts. This setup would endow participants with free choice of saccadic movement (left, right, up, down) after the word cue and attest whether, under the same conditions of the task we devised, horizontal language direction is still preponderant in biasing attention.

Finally, another research avenue would be to assess the role of moderators in the representation of abstract concepts. Individual differences, for instance, can impact the grounding of abstract concepts and shape conceptual knowledge (see Landau et al., 2010 for a discussion). Moderator variables can acquire added significance in the case of concepts that hold substantial inter-individual variability, like politics. Political orientation, knowledge, and engagement may be useful pointers to political mappings in space. For example, cueing effects in classifying left-wing parties are amplified for participants yielding a strong political rightward leaning (van Elk et al., 2010). This suggests that people rely on their own position to anchor further social judgments. Arguably, cueing effects may be even more differentiated in bi-party political systems (e.g., USA, UK) in which, unlike in Portugal, two parties with polarized ideologies dominate political opinion. Furthermore, political knowledge can be relevant because it indicates how connected are the source and target domains of the metaphor (a connection more intuitive with the category of time) (Lakoff & Johnson, 1980). Those more familiar with the target domain (politics) will more likely be affected by metaphorical language (Johnson & Taylor, 1981). What we have controlled for was the variance introduced by inter-individual differences in response times, which in part reflects the individual political inclinations of the participants. Individual performance did not compromise the biased association between political categories and space. It follows that the political preferences of participants were insufficient to override the effect of language direction in the mapping of politics. Nevertheless, future studies should include these moderators as covariates for a more thorough approach.

Practical Implications

The spatial bias that we report has practical downstream consequences for the representation of visual compositions in advertisement and marketing domains. Consumers incorporate the horizontal location of products in retail displays into inferences of price, quality, and popularity (Valenzuela et al., 2013) and ad layouts that coincide with the cultural mapping of time influence attitudes towards time-related products (Chae & Hoegg, 2013). Likewise, ads featuring objects implying left-to-right motion increase brand trust relative to objects portrayed in a right-to-left orientation (Cian et al., 2014; Monahan & Romero, 2020). Moreover, script-consistent layouts are processed with greater ease because this direction 'feels right' to consumers, and is subsequently used to generate appraisals of brand trust (Avnet & Higgins, 2006; Cesario et al., 2008). Overall, this evidence reiterates that seemingly irrelevant features of visual presentation (e.g., horizontal position, facing direction) operate in a convention-based system governed by culture that establishes expectations on how visuals should be organized (Scott, 1994).

The spatial bias underlying profile faces, and representation of time and political concepts carries implications not just to domains of consumer persuasion but to any ecological context wishing to imprint a particular message through the arrangement of elements in space. Our results provide guidance to content managers in advertising and political marketing on how to capitalize on people's implicit associations between movement and space. Further, they underscore that visual compositions ought to evoke a sense of cultural coherence to promote ease of processing and message effectiveness (Cesario et al., 2008). This cultural coherence is achieved by tailoring both the message and the visual components to people's expectations.

For example, outputs from the study showing that right profiles evoke agency-correlated traits can easily be transported to outdoors and printed ad construction. If field practitioners of any domain wish to connote people and products with features of powerfulness, dominance, and assertiveness, they are advised to represent them graphically facing and/or moving rightward (Chatterjee, 2002; Maass et al., 2007; Suitner et al., 2017). Emphasizing these features is particularly relevant for political campaigning where politicians want to associate themselves with a certain dynamism and industriousness. The two studies with right faces serving as attentional cues also indicate that they speed up attention and facilitate processing on the right space to a greater extent. One can surmise that text (e.g., slogans, headlines, product specs) presented to the right of the directional image will be preferentially attended to (and processed) because people anticipate novel information to occur as one progresses to the right. Above all other arrangements, westerners seem to prefer script-congruent layouts that combine rightward motion 'leading to' a verbal message positioned on the right (Suitner & Maass, 2016). As we observed, movement representations that deviate from normative expectations (i.e., that instigate unhabitual eye-movement) are likely to disengage viewer's attention, a much unsought output for marketers.

In everyday life, people are bombarded with an abundance of stimuli and have limited time and variable motivation to process them. Capturing people's attention quickly becomes crucial. People commonly lack the full information needed to make purchasing decisions or formulate inferences about someone else's character. Therefore, people extract cues from advertising that are used to signal trust judgments (Erdem & Swait, 1998). For example, 100 ms of exposure of a political candidate is enough to draw superficial trait inferences that impact voters' decisions (Willis & Todorov, 2006). Visual cues are therefore critical to influence instantaneous judgments when people have little to no a priori information. In situations of uncertainty, people exhibit a '*preference for the norm'* consistent with the standard they are accustomed to, favoring more typical and expected options (Campbell & Goodstein, 2001, p. 440). In line with this evidence, our research suggests that stylistic aspects of materials should be carefully thought out by advertisers to reflect the dominant directionality in a given culture and hence maximize evaluations. Results from studies demonstrating that time and political words induce a movement bias consistent with script direction may contribute to marketers in these domains (and may be extrapolated to the representation of other abstract concepts as well). For example, it is directly applicable in campaigns promoting weight loss programs with 'before and after' visual representations. Our research tells us that people will respond more favorably to such contents, and others implying the progression of time or time-related objects, when they are aligned with cultural preferences (e.g., 'before' images on the left for left-to-right language speakers, and on the right for right-to-left language speakers). The same goes for politics. Political spatial metaphors may aid in the construal of people's political decisions and their own positioning in the political spectrum. Previous research has shown that even the location of polling stations and the candidates' names on the ballot paper can influence voting decisions (Berger et al., 2008; Krosnick et al., 2004). Aside from the consequences of representing political figures in layouts (positioning should match the politicians' inclination and the salient political mapping in a culture), campaign managers aware of this phenomenon may utilize political metaphor as a tool to (not so incidentally) prime electors to their candidate's ideology. This level of influence is unlikely for people with inflexible convictions (Robins & Mayer, 2000), but may be effective to sway a significant audience holding ambivalent and malleable political attitudes (Converse, 2000). Overall, the research we report has clear managerial implications. It calls for the need to devise culturally adapted interfaces customized to conform to the prevalent script direction, should marketers hope to better make their narrative come across to consumers and social targets.

Final Remarks

The research compiled in this dissertation reveals that an apparently arbitrary aspect of language like the directionality of its written script can induce spatial biases that modulate perceptuo-motor skills and conceptual representations. We show that spatial biases are by no means universal but are instead tied to cultural variations manifested by language direction. This feature of language, fueled by habitual reading and writing routines and consolidated by cultural regularities, establishes mental schemas that serve as a compass to navigate our social world, anticipate consequences, perform actions, and reason about abstract content. The natural space-movement correlation supplied by language and culture forges a long-term bias that shapes how human agency is conceived. Through repeated training and chronic exposure, the spatial bias becomes embodied and its original bodily experience is further recruited to aid in the comprehension of other abstract categories devoid of sensorimotor bases. The mental metaphors people use to structure these elusive domains are manifested in linguistic conventions that retain and perpetuate left-right associations no longer needing physical experiencing.

In seven studies, we demonstrated that people import their dominant reading direction (or the perception of movement) into diverse inferential processes. Our evidence shows that directional scanning habits influence cognitive tasks that range from the social field of person perception to the uttermost basic representation of information that does not afford direct sensorimotor links. In other words, the movement direction is the common denominator underlying how people formulate social judgments about others, and how they reason about abstract language used to construe time and politics. The spatial bias produced systematic convergent effects across tasks (social judgment, spatial cueing), stimuli (faces, words), and modalities (visual, auditory) in fundamental processes of orientation of attention and motor performance, initially conceived as ‘culture-free’ and immune to situated pressures.

The contribution of this dissertation is to be seen in that the way semantically dissimilar inferences and concepts are grounded is a unifying principle. Evidently, we do not argue that abstract representations are shared by all people at all times because thought is contaminated by dynamic social experience. In our view, the conceptual overlap between these heterogeneous materials producing similar results rests, for the most part, on the culturally-anchored movement direction. This means that the representation of motion comprises a generic property that binds a variety of mental processes and representations. Further, these studies add to the body of literature documenting that spatial thought is shaped by stored corporeal information activated upon demands of the context. We observed these ideomotor implications objectively in ocular movement performance that mimicked the direction of the physical activities of reading and writing.

This dissertation represents a contribution to research on embodiment, visual processing, and social and cognitive psychology. The demonstrated effects of cultural scanning habits on spatial decisions add generalizability to prior findings stressing the implications of the spatial agency bias and open the way for future research endeavors. However, while extensions of this work to other concepts and metaphors would be praiseworthy, literature has devoted limited attention to study how reading habits affect judgment and memory of these concepts in concrete and easily identifiable real-life situations.

Altogether, this work underscores that social agents do not operate in a vacuum. Although our experience of the world is only physical, our internal mental lives are rich enough to span well beyond material elements. Humans have turned to features space, language, and culture to better grasp and articulate what is less tangible. Yet, it is difficult to pinpoint the origins of spatial biases in human behavior because they stem from cultural, linguistic, and bodily patterns that appear mutually inextricable. This work is one step further in that direction.

References

Abed, F. (1991). Cultural influences on visual scanning patterns. *Journal of Cross-Cultural Psychology*, *22*(4), 525–534. https://doi.org/10.1177/0022022191224006

Abele, A. E. (2003). The Dynamics of Masculine-Agentic and Feminine-Communal Traits: Findings from a Prospective Study. *Journal of Personality and Social Psychology*. https://doi.org/10.1037/0022-3514.85.4.768

Abele, A. E., Uchronski, M., Suitner, C., & Wojciszke, B. (2008). Towards an operationalization of the fundamental dimensions of agency and communion: Trait content ratings in five countries considering valence and frequency of word occurrence. *European Journal of Social Psychology*, *38*(7), 1202–1217. https://doi.org/10.1002/ejsp.575

Abele, A. E., & Wojciszke, B. (2014). Communal and agentic content in social cognition: A dual perspective model. *Advances in Experimental Social Psychology*, *50*, 195–255. https://doi.org/10.1016/B978-0-12-800284-1.00004-7

Afsari, Z., Keshava, A., Ossandón, J. P., & König, P. (2018). Interindividual differences among native right-to-left readers and native left-to-right readers during free viewing task. *Visual Cognition*, *26*(6), 430–441. https://doi.org/10.1080/13506285.2018.1473542

Allison, T., Puce, A., & McCarthy, G. (2000). Social perception from visual cues: Role of the STS region. In *Trends in Cognitive Sciences* (Vol. 4, Issue 7, pp. 267–278). Elsevier Current Trends. https://doi.org/10.1016/S1364-6613(00)01501-1

Andrews, B., Aisenberg, D., D'Avossa, G., & Sapir, A. (2013). Cross-cultural effects on the assumed light source direction: Evidence from English and Hebrew readers. *Journal of Vision*, *13*(13:2), 1–7. https://doi.org/10.1167/13.13.2

Avnet, T., & Higgins, E. T. (2006). How regulatory fit affects value in consumer choices and opinions. *Journal of Marketing Research*, *43*(1), 1–10. https://doi.org/10.1509/jmkr.43.1.1

Bakhtin, M. M. (1981). *The dialogic imagination: Four essays* (M. Holquist (ed.)). University of Texas Press.

Barnhart, W. R., Rivera, S., & Robinson, C. W. (2018). Different patterns of modality dominance across development. *Acta Psychologica, 182,* 154–165. https://doi.org/10.1016/j.actpsy.2017.11.017

Barsalou, L. W. (1999). Language comprehension: Archival memory or preparation for situated action? In *Discourse Processes* (Vol. 28, Issue 1, pp. 61–80). Routledge. https://doi.org/10.1080/01638539909545069

Barsalou, L. W. (2008). Grounded Cognition. *Annual Review of Psychology*, *59*(1), 617–645. https://doi.org/10.1146/annurev.psych.59.103006.093639

Beard, A. (2003). *The Language of Politics*. Routledge.

Berger, J., Meredith, M., & Wheeler, S. C. (2008). Contextual priming: Where people vote affects how they vote. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(26), 8846–8849. https://doi.org/10.1073/pnas.0711988105

Bettinsoli, M. L., Maass, A., & Suitner, C. (2019). The first, the least and the last: Spatial asymmetries in memory and their relation to script trajectory. *Memory and Cognition*, *47*, 229–239. https://doi.org/10.3758/s13421-018-0861-1

Boroditsky, L. (2011). How languages construct time. In *Space, Time and Number in the Brain* (pp. 333–341). Elsevier Inc. https://doi.org/10.1016/B978-0-12-385948-8.00020-7

Boroditsky, L., Fuhrman, O., & McCormick, K. (2011). Do English and Mandarin speakers think about time differently? *Cognition*, *118*(1), 123–129. https://doi.org/10.1016/j.cognition.2010.09.010

Boroditsky, L., & Gaby, A. (2010). Remembrances of times east: Absolute spatial representations of time in an Australian aboriginal community. *Psychological Science*, *21*(11), 1635–1639. https://doi.org/10.1177/0956797610386621

Boroditsky, L., & Ramscar, M. (2002). The roles of body and mind in abstract thought. *Psychological Science*, *13*(2), 185–189. https://doi.org/10.1111/1467-9280.00434

Bradshaw, J. L., Nathan, G., Nettleton, N. C., Wilson, L., & Pierson, J. (1987). Why is there a left side underestimation in rod bisection? *Neuropsychologia*, *25*(4), 735–738. https://doi.org/10.1016/0028-3932(87)90067-4

Callizo-Romero, C., Tutnjević, S., Pandza, M., Ouellet, M., Kranjec, A., Ilić, S., Gu, Y., Göksun, T., Chahboun, S., Casasanto, D., & Santiago, J. (2020). Temporal focus and time spatialization across cultures. *Psychonomic Bulletin and Review*, *27*(6), 1247–1258. https://doi.org/10.3758/s13423-020-01760-5

Campbell, M. C., & Goodstein, R. C. (2001). The moderating effect of perceived risk on consumers' evaluations of product incongruity: Preference for the norm. *Journal of Consumer Research*, *28*(3), 439–449. https://doi.org/10.1086/323731

Carnaghi, A., Piccoli, V., Brambilla, M., & Bianchi, M. (2014). Gender hierarchy in the space: The role of gender status in shaping the spatial agency bias. *The Journal of Social Psychology*, *154*(2), 105–114. https://doi.org/10.1080/00224545.2013.863174

Casasanto, D. (2013). Experiential origins of mental metaphors: Language, culture, and the body. In *The power of metaphor: Examining its influence on social life.* (pp. 249–268). American Psychological Association. https://doi.org/10.1037/14278-011

Casasanto, D., & Jasmin, K. (2012). The hands of time: Temporal gestures in english speakers. *Cognitive Linguistics*, *23*(4), 643 – 674. https://doi.org/10.1515/cog-2012-0020

Cesario, J., Higgins, E. T., & Scholer, A. A. (2008). Regulatory fit and persuasion: Basic principles and remaining questions. *Social and Personality Psychology Compass*, *2*(1), 444–463. https://doi.org/10.1111/j.1751-9004.2007.00055.x

Chae, B., & Hoegg, J. (2013). The future looks “right”: Effects of the horizontal location of advertising images on product attitude. *Journal of Consumer Research*, *40*(2), 223–238. https://doi.org/10.1086/669476

Chahboun, S., Flumini, A., Pérez González, C., McManus, I. C., & Santiago, J. (2017). Reading and writing direction effects on the aesthetic appreciation of photographs. *Laterality: Asymmetries of Body, Brain and Cognition*, *22*(3), 313–339. https://doi.org/10.1080/1357650X.2016.1196214

Chatterjee, A. (2002). Portrait Profiles and the Notion of Agency. *Empirical Studies of the Arts*. https://doi.org/10.2190/3wlf-agtv-0aw7-r2cn

Chatterjee, A., Southwood, M. H., & Basilico, D. (1999). Verbs, events and spatial representations. *Neuropsychologia*, *37*(4), 395–402. https://doi.org/10.1016/S0028-3932(98)00108-0

Cho, Y. S., & Proctor, R. W. (2003). Stimulus and response representations underlying orthogonal stimulus-response compatibility effects. *Psychonomic Bulletin and Review*, *10*(1), 45–73. https://doi.org/10.3758/BF03196468

Chokron, S., Bartolomeo, P., Perenin, M. T., Helft, G., & Imbert, M. (1998). Scanning direction and line bisection: A study of normal subjects and unilateral neglect patients with opposite reading habits. *Cognitive Brain Research*, *7*(2), 173–178. https://doi.org/10.1016/S0926-6410(98)00022-6

Chokron, S., & De Agostini, M. (2000). Reading habits influence aesthetic preference. *Cognitive Brain Research*, *10*(1–2), 45–49. https://doi.org/10.1016/S0926-6410(00)00021-5

Chokron, S., & Imbert, M. (1993). Influence of reading habits on line bisection. *Cognitive Brain Research*, *1*(4), 219–222. https://doi.org/10.1016/0926-6410(93)90005-P

Cian, L., Krishna, A., & Elder, R. S. (2014). This logo moves me: Dynamic imagery from static images. *Journal of Marketing Research*, *51*(2), 184–197. https://doi.org/10.1509/jmr.13.0023

Clark, H. H. (1973). Space, time, semantics, and the child. In T. Moore (Ed.), *Cognitive Development and the Acquisition of Language* (pp. xii, 308–xii, 308). Academic Press.

Connell, L., & Lynott, D. (2012). Strength of perceptual experience predicts word processing performance better than concreteness or imageability. *Cognition*, *125*(3), 452–465. https://doi.org/10.1016/j.cognition.2012.07.010

Converse, P. E. (2000). Assessing the capacity of mass electorates. *Annual Review of Political*

Science, *3*(1), 331–353. https://doi.org/10.1146/annurev.polisci.3.1.331

de Sousa, H. (2012). Generational differences in the orientation of time in Cantonese speakers as a function of changes in the direction of Chinese writing. *Frontiers in Psychology*, *3*(JUL), 255. https://doi.org/10.3389/fpsyg.2012.00255

Dijkstra, K., Eerland, A., Zijlmans, J., & Post, L. S. (2012). How body balance influences political party evaluations: A Wii balance board study. *Frontiers in Psychology*, *3*(DEC), 536. https://doi.org/10.3389/fpsyg.2012.00536

Ding, X., Feng, N., He, T., Cheng, X., & Fan, Z. (2020). Can mental time lines co-exist in 3D space? *Acta Psychologica*, *207*, 103084. https://doi.org/10.1016/j.actpsy.2020.103084

Eimer, M., & Velzen, J. (2002). Crossmodal links in spatial attention are mediated by supramodal control processes: Evidence from event-related potentials. *Psychophysiology*, *39*(4), 437–449. https://doi.org/10.1111/1469-8986.3940437

Erdem, T., & Swait, J. (1998). Brand equity as a signaling phenomenon. *Journal of Consumer Psychology*, *7*(2), 131–157. https://doi.org/10.1207/s15327663jcp0702_02

Eviatar, Z. (1997). Language experience and right hemisphere tasks: The effects of scanning habits and multilingualism. *Brain and Language*, *58*(1), 157–173. https://doi.org/10.1006/brln.1997.1863

Farias, A. R., Garrido, M. V., & Semin, G. R. (2013). Converging modalities ground abstract categories: The case of politics. *PLoS ONE*, *8*(4), e60971. https://doi.org/10.1371/journal.pone.0060971

Farias, A. R., Garrido, M. V., & Semin, G. R. (2016). Embodiment of abstract categories in space. . . grounding or mere compatibility effects? The case of politics. *Acta Psychologica*, *166*, 49–53. https://doi.org/10.1016/j.actpsy.2016.03.002

Fischer, B. (1998). Attention in saccades. In *Visual Attention* (pp. 289–305). Oxford University Press.

Fiske, S. T., Cuddy, A. J. C., Glick, P., & Xu, J. (2002). A model of (often mixed) stereotype content: Competence and warmth respectively follow from perceived status and competition. *Journal of Personality and Social Psychology*. https://doi.org/10.1037/0022-3514.82.6.878

Fitts, P. M., & Seeger, C. M. (1953). S-R compatibility: spatial characteristics of stimulus and response codes. *Journal of Experimental Psychology*, *46*(3), 199–210. https://doi.org/10.1037/h0062827

Flath, M. E., Smith, A. K., & Elias, L. J. (2019). Cultural differences in lateral biases on aesthetic judgments: The effect of native reading direction. *Culture and Brain*, *7*(1), 57–66. https://doi.org/10.1007/s40167-018-0062-6

Flumini, A., & Santiago, J. (2013). Time (also) flies from left to right... if it is needed! In *Proceedings of the Annual Meeting of the Cognitive Science Society* (pp. 2315–2320).

Fort, A., Delpuech, C., Pernier, J., & Giard, M.-H. (2002). Dynamics of Cortico-subcortical Cross-modal Operations Involved in Audio-visual Object Detection in Humans. *Cerebral Cortex*, *12*(10), 1031–1039. https://doi.org/10.1093/cercor/12.10.1031

Freyd, J. J. (1987). Dynamic mental representations. *Psychological Review*, *94*(4), 427–438. https://doi.org/10.1037/0033-295X.94.4.427

Friedrich, T. E., & Elias, L. J. (2016). The write bias: The influence of native writing direction on aesthetic preference biases. *Psychology of Aesthetics, Creativity, and the Arts*, *10*(2), 128–133. https://doi.org/10.1037/aca0000055

Friesen, C. K., & Kingstone, A. (1998). The eyes have it! Reflexive orienting is triggered by nonpredictive gaze. *Psychonomic Bulletin and Review*, *5*(3), 490–495. https://doi.org/10.3758/BF03208827

Frischen, A., Bayliss, A. P., & Tipper, S. P. (2007). Gaze cueing of attention: Visual attention, social cognition, and individual differences. *Psychological Bulletin*, *133*(4), 694–724. https://doi.org/10.1037/0033-2909.133.4.694

Fuhrman, O., & Boroditsky, L. (2010). Cross-cultural differences in mental representations of time: Evidence from an implicit nonlinguistic task. *Cognitive Science*, *34*(8), 1430–1451. https://doi.org/10.1111/j.1551-6709.2010.01105.x

Gibson, B. S., & Kingstone, A. (2006). Visual attention and the semantics of space: beyond central and peripheral cues. *Psychological Science*, *17*(7), 622–627. https://doi.org/10.1111/j.1467-9280.2006.01754.x

Hartmann, M., Grabherr, L., & Mast, F. W. (2012). Moving along the mental number line: Interactions between whole-body motion and numerical cognition. *Journal of Experimental Psychology: Human Perception and Performance*, *38*(6), 1416–1427. https://doi.org/10.1037/a0026706

Hauk, O., Johnsrude, I., & Pulvermüller, F. (2004). Somatotopic representation of action words in human motor and premotor cortex. *Neuron*, *41*(2), 301–307. https://doi.org/10.1016/S0896-6273(03)00838-9

Hitlin, S., & Elder, G. H. (2007). Time, self, and the curiously abstract concept of agency*. *Sociological Theory*. https://doi.org/10.1111/j.1467-9558.2007.00303.x

Hoffman, E. A., & Haxby, J. V. (2000). Distinct representations of eye gaze and identity in the distributed human neural system for face perception. *Nature Neuroscience*. https://doi.org/10.1038/71152

Hommel, B., Pratt, J., Colzato, L., & Godijn, R. (2001). Symbolic control of visual attention.

Psychological Science, *12*(5), 360–365. https://doi.org/10.1111/1467-9280.00367

Humphreys, G. W. (2013). Beyond serial stages for attentional selection: The critical role of action. In *Action Science* (pp. 228–251). The MIT Press. https://doi.org/10.7551/mitpress/9780262018555.003.0009

Humphreys, G. W., & Riddoch, M. J. (2007). Knowing what you need but not what you want: affordances and action-defined templates in neglect. *Behavioural Neurology*, *13*(1–2), 75–87. https://doi.org/10.1155/2002/635685

Jewell, G., & McCourt, M. E. (2000). Pseudoneglect: A review and meta-analysis of performance factors in line bisection tasks. *Neuropsychologia*, *38*(1), 93–110. https://doi.org/10.1016/S0028-3932(99)00045-7

Johnson, J. T., & Taylor, S. E. (1981). The effect of metaphor on political attitudes. *Basic and Applied Social Psychology*, *2*(4), 305–316. https://doi.org/10.1207/s15324834basp0204_6

Koelewijn, T., Bronkhorst, A., & Theeuwes, J. (2009). Auditory and visual capture during focused visual attention. *Journal of Experimental Psychology: Human Perception and Performance*, *35*(5), 1303–1315. https://doi.org/10.1037/a0013901

Kranjec, A., & Chatterjee, A. (2010). Are temporal concepts embodied? A challenge for cognitive neuroscience. *Frontiers in Psychology*, *1*(DEC), 240. https://doi.org/10.3389/fpsyg.2010.00240

Krosnick, J. A., Miller, J. M., & Tichy, M. P. (2004). An unrecognized need for ballot reform: Effects of candidate name order. In A. M. Crigler, M. R. Just, & E. J. McCaffery (Eds.), *Rethinking the vote: The politics and prospects of American election reform* (pp. 51–74). Oxford University Press.

Lakens, D., Semin, G. R., & Garrido, M. V. (2011). The sound of time: Cross-modal convergence in the spatial structuring of time. *Consciousness and Cognition*, *20*(2), 437–443. https://doi.org/10.1016/j.concog.2010.09.020

Lakoff, G., & Johnson, M. H. (1980). The metaphorical structure of the human conceptual system. *Cognitive Science*, *4*, 195–208. https://doi.org/10.1016/S0364-0213(80)80017-6

Lakoff, G., & Johnson, M. H. (1999). *Philosophy in the flesh : the embodied mind and its challenge to Western thought*. Basic Books.

Landau, M. J., Meier, B. P., & Keefer, L. A. (2010). A metaphor-enriched social cognition. *Psychological Bulletin*, *136*(6), 1045–1067. https://doi.org/10.1037/a0020970

Langton, S. R. H., & Bruce, V. (1999). Reflexive visual orienting in response to the social attention of others. *Visual Cognition*. https://doi.org/10.1080/135062899394939

Lavie, N. (2005). Distracted and confused?: Selective attention under load. In *Trends in Cognitive Sciences* (Vol. 9, Issue 2, pp. 75–82). Elsevier Current Trends.

https://doi.org/10.1016/j.tics.2004.12.004

Lee, A. Y., & Aaker, J. L. (2004). Bringing the frame into focus: The influence of regulatory fit on processing fluency and persuasion. *Journal of Personality and Social Psychology*, *86*(2), 205–218. https://doi.org/10.1037/0022-3514.86.2.205

Levander, M., Tegnér, R., & Caneman, G. (1993). Tactile line-bisection in normal subjects. *Perceptual and Motor Skills*, *76*(3 Pt 1), 831–836. https://doi.org/10.2466/pms.1993.76.3.831

Maass, A., Pagani, D., & Berta, E. (2007). How beautiful is the goal and how violent is the fistfight? Spatial bias in the interpretation of human behavior. *Social Cognition*, *25*(6), 833–852. https://doi.org/10.1521/soco.2007.25.6.833

Maass, A., Suitner, C., Favaretto, X., & Cignacchi, M. (2009). Groups in space: Stereotypes and the spatial agency bias. *Journal of Experimental Social Psychology*, *45*(3), 496–504. https://doi.org/10.1016/j.jesp.2009.01.004

Mandal, M. K., & Ambady, N. (2004). Laterality of facial expressions of emotion: Universal and culture-specific influences. *Behavioural Neurology*, *15*, 23–34.

Meier, B. P., & Robinson, M. D. (2004). Why the sunny side is up: Associations between affect and vertical position. *Psychological Science*, *15*(4), 243–247. https://doi.org/10.1111/j.0956-7976.2004.00659.x

Mills, M., Smith, K. B., Hibbing, J. R., & Dodd, M. D. (2015). Obama cares about visuo-spatial attention: Perception of political figures moves attention and determines gaze direction. *Behavioural Brain Research*, *278*, 221–225. https://doi.org/10.1016/j.bbr.2014.09.048

Monahan, L., & Romero, M. (2020). Heading the right way? The influence of motion direction in advertising on brand trust. *Journal of Advertising*, *49*(3), 250–269. https://doi.org/10.1080/00913367.2020.1751010

Morikawa, K., & McBeath, M. K. (1992). Lateral motion bias associated with reading direction. *Vision Research*, *32*(6), 1137–1141. https://doi.org/https://doi.org/10.1016/0042-6989(92)90014-A

Ngo, M. K., Pierce, R. S., & Spence, C. (2012). Using multisensory cues to facilitate air traffic management. *Human Factors*, *54*(6), 1093–1103. https://doi.org/10.1177/0018720812446623

Ngo, M. K., & Spence, C. (2010). Auditory, tactile, and multisensory cues facilitate search for dynamic visual stimuli. *Attention, Perception, and Psychophysics*, *72*(6), 1654–1665. https://doi.org/10.3758/APP.72.6.1654

Niedenthal, P. M., Winkielman, P., Mondillon, L., & Vermeulen, N. (2009). Embodiment of emotion concepts. *Journal of Personality and Social Psychology*, *96*(6), 1120–1136.

https://doi.org/10.1037/a0015574

Oosterhof, N. N., & Todorov, A. (2008). The functional basis of face evaluation. *Proceedings of the National Academy of Sciences of the United States of America*. https://doi.org/10.1073/pnas.0805664105

Oppenheimer, D. M., & Trail, T. E. (2010). Why leaning to the left makes you lean to the left: Effect of spatial orientation on political attitudes. *Social Cognition*, *28*(5), 651–661. https://doi.org/10.1521/soco.2010.28.5.651

Ossandón, J. P., Onat, S., & König, P. (2014). Spatial biases in viewing behavior. *Journal of Vision*, *14*(2), 1–26. https://doi.org/10.1167/14.2.20

Ouellet, M., Santiago, J., Funes, M. J., & Lupiáñez, J. (2010). Thinking about the future moves attention to the right. *Journal of Experimental Psychology: Human Perception and Performance*, *36*(1), 17–24. https://doi.org/10.1037/a0017176

Ouellet, M., Santiago, J., Israeli, Z., & Gabay, S. (2010). Is the future the right time? *Experimental Psychology*, *57*(4), 308–314. https://doi.org/10.1027/1618-3169/a000036

Peeters, G. (1992). Evaluative meanings of adjectives in vitro and in context: Some theoretical implications and practical consequences of positive-negative asymmetry and behavioral-adaptive concepts of evaluation. *Psychologica Belgica*, *32*(2), 211–231.

Phalet, K., & Poppe, E. (1997). Competence and morality dimensions of national and ethnic stereotypes: a study in six eastern-European countries. *European Journal of Social Psychology*, *27*(6), 703–723. https://doi.org/https://doi.org/10.1002/(SICI)1099-0992(199711/12)27:6<703::AID-EJSP841>3.0.CO;2-K

Pitt, B., & Casasanto, D. (2019). The correlations in experience principle: How culture shapes concepts of time and number. *Journal of Experimental Psychology: General*, *32*, 3–25. https://doi.org/10.1037/xge0000696

Pollatsek, A., Bolozky, S., Well, A. D., & Rayner, K. (1981). Asymmetries in the perceptual span for Israeli readers. *Brain and Language*, *14*(1), 174–180. https://doi.org/10.1016/0093-934X(81)90073-0

Rashidi-Ranjbar, N., Goudarzvand, M., Jahangiri, S., Brugger, P., & Loetscher, T. (2014). No horizontal numerical mapping in a culture with mixed-reading habits. *Frontiers in Human Neuroscience, 8*(72), 1–5. https://doi.org/10.3389/fnhum.2014.00072

Reuter-Lorenz, P. A., Kinsbourne, M., & Moscovitch, M. (1990). Hemispheric control of spatial attention. *Brain and Cognition*, *12*(2), 240–266. https://doi.org/10.1016/0278-2626(90)90018-J

Richardson, D. C., Spivey, M. J., Barsalou, L. W., & McRae, K. (2003). Spatial representations activated during real-time comprehension of verbs. *Cognitive Science*, *27*(5), 767–780.

https://doi.org/10.1016/S0364-0213(03)00064-8

Rinaldi, L., Di Luca, S., Henik, A., & Girelli, L. (2014). Reading direction shifts visuospatial attention: An interactive account of attentional biases. *Acta Psychologica*, *151*, 98–105. https://doi.org/10.1016/j.actpsy.2014.05.018

Robins, S., & Mayer, R. E. (2000). The metaphor framing effect: Metaphorical reasoning about text-based dilemmas. *Discourse Processes*, *30*(1), 57–86. https://doi.org/10.1207/S15326950dp3001_03

Robinson, C. W., & Sloutsky, V. M. (2010). Development of cross-modal processing. *Wiley Interdisciplinary Reviews: Cognitive Science*, *1*(1), 135–141. https://doi.org/10.1002/wcs.12

Román, A., Flumini, A., Lizano, P., Escobar, M., & Santiago, J. (2015). Reading direction causes spatial biases in mental model construction in language understanding. *Scientific Reports*, *5*, 18248. https://doi.org/10.1038/srep18248

Santangelo, V., Van Der Lubbe, R. H. J., Belardinelli, M. O., & Postma, A. (2006). Spatial attention triggered by unimodal, crossmodal, and bimodal exogenous cues: A comparison of reflexive orienting mechanisms. *Experimental Brain Research*, *173*(1), 40–48. https://doi.org/10.1007/s00221-006-0361-6

Santiago, J., Lupiáñez, J., Pérez, E., & Funes, M. J. (2007). Time (also) flies from left to right. *Psychonomic Bulletin and Review, 14*, 512–516. https://doi.org/10.3758/BF03194099

Santiago, J., Ouellet, M., Román, A., & Valenzuela, J. (2012). Attentional factors in conceptual congruency. *Cognitive Science*, *36*(6), 1051–1077. https://doi.org/10.1111/j.1551-6709.2012.01240.x

Santiago, J., Román, A., & Ouellet, M. (2011). Flexible foundations of abstract thought: A review and a theory. In *Spatial Dimensions of Social Thought* (pp. 39–108). De Gruyter Mouton. https://doi.org/10.1515/9783110254310.39

Santiago, J., Román, A., Ouellet, M., Rodríguez, N., & Pérez-Azor, P. (2010). In hindsight, life flows from left to right. *Psychological Research*, *74*(1), 59–70. https://doi.org/10.1007/s00426-008-0220-0

Scott, L. M. (1994). Images in advertising: The need for a theory of visual rhetoric. *Journal of Consumer Research*, *21*(2), 252. https://doi.org/10.1086/209396

Selcon, S. J., Taylor, R. M., & McKenna, F. P. (1995). Integrating multiple information sources: Using redundancy in the design of warnings. *Ergonomics*, *38*(11), 2362–2370. https://doi.org/10.1080/00140139508925273

Simon, J. R., & Craft, J. L. (1970). Effects of an irrelevant auditory stimulus on visual choice reaction time. *Journal of Experimental Psychology*, *86*(2), 272–274.

https://doi.org/10.1037/h0029961

Sinnett, S., Soto-Faraco, S., & Spence, C. (2008). The co-occurrence of multisensory competition and facilitation. *Acta Psychologica*, *128*(1), 153–161. https://doi.org/10.1016/j.actpsy.2007.12.002

Sinnett, S., Spence, C., & Soto-Faraco, S. (2007). Visual dominance and attention: The Colavita effect revisited. *Perception & Psychophysics*, *69*(5), 673–686. https://doi.org/10.3758/BF03193770

Smith, A. K., & Elias, L. J. (2013). Native reading direction and corresponding preferences for left- or right-lit images. *Perceptual and Motor Skills*, *116*(2), 355–367. https://doi.org/10.2466/23.24.PMS.116.2.355-367

Spalek, T. M., & Hammad, S. (2004). Supporting the attentional momentum view of IOR: Is attention biased to go right? *Perception and Psychophysics*, *66*, 219–233. https://doi.org/10.3758/BF03194874

Spalek, T. M., & Hammad, S. (2005). The left-to-right bias in inhibition of return is due to the direction of reading. *Psychological Science*, *16*(1), 15–18. https://doi.org/10.1111/j.0956-7976.2005.00774.x

Spence, C., & Driver, J. (1997). Audiovisual links in exogenous covert spatial orienting. *Perception and Psychophysics*, *59*(1), 1–22. https://doi.org/10.3758/BF03206843

Spence, C., & Driver, J. (2012). Crossmodal space and crossmodal attention. In *Crossmodal Space and Crossmodal Attention*. Oxford University Press. https://doi.org/10.1093/acprof:oso/9780198524861.001.0001

Spence, C., & Santangelo, V. (2009). Capturing spatial attention with multisensory cues: A review. *Hearing Research*, *258*(1–2), 134–142. https://doi.org/10.1016/j.heares.2009.04.015

Stanfield, R. A., & Zwaan, R. A. (2001). The effect of implied orientation derived from verbal context on picture recognition. *Psychological Science*, *12*(2), 153–156. https://doi.org/10.1111/1467-9280.00326

Stein, B. E., London, N., Wilkinson, L. K., & Price, D. D. (1996). Enhancement of perceived visual intensity by auditory stimuli: A psychophysical analysis. *Journal of Cognitive Neuroscience, 8*(6), 497–506. https://doi.org/10.1162/jocn.1996.8.6.497

Stein, B. E., & Stanford, T. R. (2008). Multisensory integration: Current issues from the perspective of the single neuron. *Nature Reviews Neuroscience*, *9*(4), 255–266. https://doi.org/10.1038/nrn2331

Suitner, C., & Maass, A. (2016). Spatial agency bias: Representing people in space. *Advances in Experimental Social Psychology*, *53*, 245–301.

https://doi.org/10.1016/bs.aesp.2015.09.004

Suitner, C., Maass, A., & Ronconi, L. (2017). From spatial to social asymmetry: Spontaneous and conditioned associations of gender and space. *Psychology of Women Quarterly*, *41*(1), 46–64. https://doi.org/10.1177/0361684316676045

Sutherland, C. A. M., Young, A. W., & Rhodes, G. (2017). Facial first impressions from another angle: How social judgements are influenced by changeable and invariant facial properties. *British Journal of Psychology*, *108*(2), 397–415. https://doi.org/10.1111/bjop.12206

Talsma, D., Senkowski, D., Soto-Faraco, S., & Woldorff, M. G. (2010). The multifaceted interplay between attention and multisensory integration. In *Trends in Cognitive Sciences* (Vol. 14, Issue 9, pp. 400–410). Elsevier Current Trends. https://doi.org/10.1016/j.tics.2010.06.008

Torralbo, A., Santiago, J., & Lupiáñez, J. (2006). Flexible conceptual projection of time onto spatial frames of reference. *Cognitive Science*, *30*(4), 745–757. https://doi.org/10.1207/s15516709cog0000_67

Tversky, B., Kugelmass, S., & Winter, A. (1991). Cross-cultural and developmental trends in graphic productions. *Cognitive Psychology*, *23*(4), 515–557. https://doi.org/10.1016/0010-0285(91)90005-9

Umiltá, C., & Nicoletti, R. (1990). Spatial stimulus-response compatibility. *Advances in Psychology*, *65*(C), 89–116. https://doi.org/10.1016/S0166-4115(08)61219-4

Vaid, J., Singh, M., Sakhuja, T., & Gupta, G. C. (2002). Stroke direction asymmetry in figure drawing: Influence of handedness and reading/writing habits. *Brain and Cognition*, *48*(2–3), 597–602. https://doi.org/10.1006/brcg.2001.1424

Valenzuela, A., Raghubir, P., & Mitakakis, C. (2013). Shelf space schemas: Myth or reality? *Journal of Business Research*, *66*(7), 881–888. https://doi.org/https://doi.org/10.1016/j.jbusres.2011.12.006

Van der Burg, E., Olivers, C. N. L., Bronkhorst, A. W., & Theeuwes, J. (2008). Pip and pop: Nonspatial auditory signals improve spatial visual search. *Journal of Experimental Psychology: Human Perception and Performance*, *34*(5), 1053–1065. https://doi.org/10.1037/0096-1523.34.5.1053

van Elk, M., van Schie, H. T., & Bekkering, H. (2010). From left to right: Processing acronyms referring to names of political parties activates spatial associations. *Quarterly Journal of Experimental Psychology*, *63*(11), 2202–2219. https://doi.org/10.1080/17470218.2010.495160

Varnava, A., McCarthy, M., & Beaumont, J. G. (2002). Line bisection in normal adults:

Direction of attentional bias for near and far space. *Neuropsychologia*, *40*(8), 1372–1378. https://doi.org/10.1016/S0028-3932(01)00204-4

Vigliocco, G., Kousta, S.-T., Della Rosa, P. A., Vinson, D. P., Tettamanti, M., Devlin, J. T., & Cappa, S. F. (2014). The neural representation of abstract words: The role of emotion. *Cerebral Cortex*, *24*(7), 1767–1777. https://doi.org/10.1093/cercor/bht025

Wallace, M. T., Meredith, M. A., & Stein, B. E. (1998). Multisensory Integration in the Superior Colliculus of the Alert Cat. *Journal of Neurophysiology*, *80*(2), 1006–1010. https://doi.org/10.1152/jn.1998.80.2.1006

Ward, L. M. (1994). Supramodal and modality-specific mechanisms for stimulus-driven shifts of auditory and visual attention. *Canadian Journal of Experimental Psychology = Revue Canadienne de Psychologie Expérimentale*, *48*(2), 242–259. https://doi.org/10.1037/1196-1961.48.2.242

Ward, L. M., McDonald, J. J., & Golestani, N. (1998). Cross-modal control of attention shifts. In R. D. Wright (Ed.), *Vancouver studies in cognitive science* (Vol. 8, pp. 232–268). Oxford University Press. https://psycnet.apa.org/record/1999-02040-009

Wiggins, J. S. (1979). A psychological taxonomy of trait-descriptive terms: The interpersonal domain. *Journal of Personality and Social Psychology*. https://doi.org/10.1037/0022-3514.37.3.395

Willis, J., & Todorov, A. (2006). First impressions: Making up your mind after a 100-ms exposure to a face. *Psychological Science*. https://doi.org/10.1111/j.1467-9280.2006.01750.x

Wojciszke, B., & Abele, A. E. (2008). The primacy of communion over agency and its reversals in evaluations. *European Journal of Social Psychology*, *38*(7), 1139–1147. https://doi.org/10.1002/ejsp.549

Wojciszke, B., Bazinska, R., & Jaworski, M. (1998). On the dominance of moral categories in impression formation. *Personality and Social Psychology Bulletin*, *24*(12), 1251–1263. https://doi.org/10.1177/01461672982412001

Yaxley, R. H., & Zwaan, R. A. (2007). Simulating visibility during language comprehension. *Cognition*, *105*(1), 229–236. https://doi.org/10.1016/j.cognition.2006.09.003

Ybarra, O., Chan, E., & Park, D. (2001). Young and old adults' concerns about morality and competence. *Motivation and Emotion*, *25*(2), 85–100. https://doi.org/10.1023/A:1010633908298

Ybarra, O., Chan, E., Park, H., Burnstein, E., Monin, B., & Stanik, C. (2008). Life's recurring challenges and the fundamental dimensions: An integration and its implications for cultural differences and similarities. *European Journal of Social Psychology*, *38*(7), 1083–

1092. https://doi.org/10.1002/ejsp.559

Zwaan, R. A., & Yaxley, R. H. (2003). Spatial iconicity affects semantic relatedness judgments. *Psychonomic Bulletin and Review, 10*(4), 954–958. https://doi.org/10.3758/BF03196557