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ARTICLE

Situating language in higher-order cognition

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Abstract

Language is known to interact flexibly with non-verbal representations, but the processing mechanisms governing these interactions remain unclear. This article reviews general cognitive processes that operate across various tasks and stimulus types and argues that these processes may drive the interactions between language and cognition, regardless of whether these interactions occur cross-linguistically or within a language. These general processes include goal-directed behaviour, reliance on context-relevant semantic knowledge and attuning to task demands. An overview of existing findings suggests that resorting to language in non-verbal or multi-modal tasks may depend on how linguistic representations align with current task goals and demands. Progress in understanding these mechanisms requires theories that make specific processing predictions about how tasks and experimental contexts encourage or discourage access to linguistic knowledge. Systematic testing of alternative mechanisms is necessary to explain how and why linguistic information influences some cognitive tasks but not others.

Keywords: Language; cognition; linguistic relativity; interaction of verbal and non-verbal representations

Verbal expressions can evoke alternative states of the world that may not be present. Communicated linguistic representations may, for example, inform us about new or unknown aspects of ongoing experience, such as what a novel object is for or how to use it. Likewise, linguistic representations may mediate action planning, memory recollection or learning about the world. Thus, many ordinary cognitive activities are accompanied or supported by language. How do we integrate verbal and non-verbal stimuli when performing a task? How do linguistic expressions and non-verbal representations relate to each other?

This question is fundamental to the study of human cognition, as it concerns the relationship between basic human cognitive functions, such as language, perception and memory. An enduring approach to studying this relationship has been linguistic relativity – the idea that the language one speaks may influence the way one thinks.

Owing to its anthropological origins, this approach has primarily focused on cross-linguistic and cross-cultural comparisons, as exemplified in existing reviews (Gumperz & Levinson, 1996; Ünal & Papafragou, 2016; Wolff & Holmes, 2011). For example, Wolff and Holmes (2011) identified several ways in which language may influence thought: (a) language may meddle with task performance, e.g., by suggesting competing stimulus representations; (b) language may augment concurrent conceptual representations, e.g., by providing additional features supporting task performance; and (c) language may act as a spotlight or inducer, making certain features more salient or prime behaviour once it has been used.

However, these purported language influences on cognition are not exclusive to cross-linguistic studies (Gentner, 2003; Gentner & Goldin-Meadow, 2003). Most contemporary approaches to human cognition, such as embodied or connectionist theories, argue that interactions between linguistic and cognitive processes involve partially shared representations integrating verbal and non-verbal aspects (Barsalou, 1999; Barsalou et al., 2003; McClelland & Rogers, 2003; Patterson et al., 2007). Consistent with this view, many studies have demonstrated that verbal expressions can modulate visual perception (Estes et al., 2008; Spivey et al., 2001; Tanenhaus et al., 1995) or action planning (Glenberg & Kaschak, 2002; Zwaan & Taylor, 2006) and elicit activity in brain regions shared with perception or action planning (Hauk et al., 2004; Martin & Chao, 2001; Pulvermüller, 2018). These approaches have also emphasised the flexible and context-dependent nature of the cognitive processes involved in a task. For example, language modulations on action planning depend on the temporal overlap between language processing and planning (Borreggine & Kaschak, 2006). In general, conceptual representations are adaptive in that they may dynamically change based on contextual cues and the agent's goals (J. R. Anderson, 1991; Barsalou, 1999, 2009; Glushko et al., 2008).

Consistent with these interactive views, more recent discussions on language and cognition have incorporated single-language studies and argued for task-dependent interactive or predictive processes. For example, Lupyan (2012) argues that linguistic labels may exert top-down influences on perceptual representations. Similarly, Lupyan et al. (2020) argue that linguistic cues may minimise prediction errors in perception and action when viewed within a predictive coding framework . These proposals acknowledge other cognitive processes outside language (e.g., prediction), constraining how language operates in non-verbal tasks – an approach further elaborated here.

Nevertheless, the specific cognitive principles or constraints governing language–cognition interactions still need to be fleshed out in detail. Such principles are essential to elaborate mechanistic theories of how language operates in cognition that entail testable predictions. What leads language to meddle in a task, facilitate or hinder prediction or performance, modulate decisions or compete with alternative stimulus representations? Why do language influences often appear *ad hoc*? Just like theories of attention and perception predict what behaviours are more likely to occur in an experimental context, it must be possible to specify some principles that would increase the likelihood of specific language influences on cognitive performance and behaviour. The renewed interest in the Whorfian hypothesis in recent years, along with the flurry of studies reporting cross-linguistic and within-language effects, underscores the utility of theoretical frameworks in building theories capable of making specific predictions.

The present article reviews some principles of adult cognition that may constrain and even determine the interaction between verbal and non-verbal representations, drawing on existing cognitive psychology and neuroscience findings. Neither the

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cognitive principles nor the studies mentioned are meant to be exhaustive. Many cognitive tasks recruiting language likely entail distinct constraints on performance, as highlighted by various subfields of cognitive science (e.g., perception, memory, decision-making, and working memory). Comprehensive reviews of cross-linguistic studies can also be found elsewhere (Bohnemeyer, 2020; Samuel et al., 2019; Ünal & Papafragou, 2016). Instead, following the topic of this special issue, the aim is to propose a framework for understanding 'ad-hoc cognition' and language.

Section 1 begins by delineating the relationship between words and conceptual structures, as well as other forms of prior knowledge. Linguistic meaning and prior knowledge are not always separable because they are both acquired through experience across development and become associated with one another. Section 2 introduces the role of task goals and experimental characteristics in constraining performance, leading the cognitive system to satisfy these constraints. It then illustrates how task goals and designs may trigger the use of available linguistic information in some existing studies. Section 3 summarises these observations and suggests a tentative framework for delineating how and why linguistic knowledge modulates cognitive performance, regardless of whether these occur within speakers of the same language or across speakers of different languages.

1. Language and prior knowledge in memory

Our mind implicitly and explicitly learns a staggering array of knowledge throughout life. For example, we know that some events bring about others (causation and contingencies) and know how to perform activities or interact with objects and people in multiple contexts. As much of this knowledge can be recruited at any time as needed, it is argued that our mind possesses different kinds of memory representations (or knowledge) supporting these cognitive processes. Cognitive scientists often distinguish among different types of long-term memory acquired from prior experience and practice. Episodic memory includes context-specific memories linked to a time and space (e.g., one's lunch yesterday). Semantic memory includes generalised knowledge abstracted across similar multi-sensory experiences (e.g., typical lunches) (Tulving, 1972, 1984). Procedural memory encompasses generalised task abilities acquired from prior practice (Eichenbaum, 2010; Gupta & Cohen, 2002).

Generalised semantic knowledge includes object concepts and categories (Murphy, 2004; Smith & Medin, 1981) or structured event schemas (Franklin et al., 2020; Rumelhart, 1980; Shank & Abelson, 1977; Zacks, 2020). For example, we are familiar with various animal and tool types, as well as how to interact with them. We are also familiar with many actions and events, their typical participants and the situations in which they occur (e.g., arrests, hunts). The more extensive our experience with objects or events, the more detailed and embedded the knowledge we acquire. These conceptual representations are necessary because they enable inferences and context-appropriate actions when encountering new objects or events. For example, when faced with a novel gadget, we may infer what it is for or how to use it by assessing it against existing knowledge.

Models of concepts and semantic memory generally assume that word and sentence meanings convey conceptual representations (Kumar, 2021; Murphy, 2004). Words like *bird* or *arrest* evoke associated features or situations, including sensory features (e.g., shape) and situations where the entities involved typically

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occur (Hare et al., 2009; McNorgan et al., 2011; Stanfield & Zwaan, 2001). However, researchers often highlight the absence of one-to-one correspondence between individual words and concepts (Murphy, 2004). The meaning of some words, like *dog* and *table*, appears to refer to external categories and behave like concepts, e.g., they may have prototypical features and support categorical inferences. Still, as dictionary entries suggest, most words have multiple senses and meanings depending on sentential contexts (e.g., *turn, taller, paper)*, and many concepts that we can think of are not expressed by a single word (e.g., *dishes to taste in San Fermín's festival*). Indeed, much ambiguity-resolution research has extensively studied how linguistic meaning is computed on the spot as a function of larger phrasal, sentential or pragmatic contexts (Kaiser & Trueswell, 2004; MacDonald et al., 1994). Thus, isolated words do not necessarily correspond to unique concepts, just as vocabulary alone does not reflect the variety of ideas a language can communicate.

Nevertheless, embodied and connectionist approaches to cognition incorporate linguistic meanings – including the products of context-dependent interpretations – into semantic memory (see Figure 1). In connectionist models, for example, words are associated through learning with a distributed network of semantic features partially shared with objects and action representations (Hoffman et al., 2017; Lambon Ralph et al., 2017; McClelland et al., 2010; McClelland & Rogers, 2003; McRae et al., 1997). These models of semantic memory are experience based in that cognitive representations and linguistic meanings emerge from learning over time and are grounded in sensory–motor features distributed across the cerebral cortex (Binder & Desai, 2011; Fernandino et al., 2016; Martin & Chao, 2001). In this view,

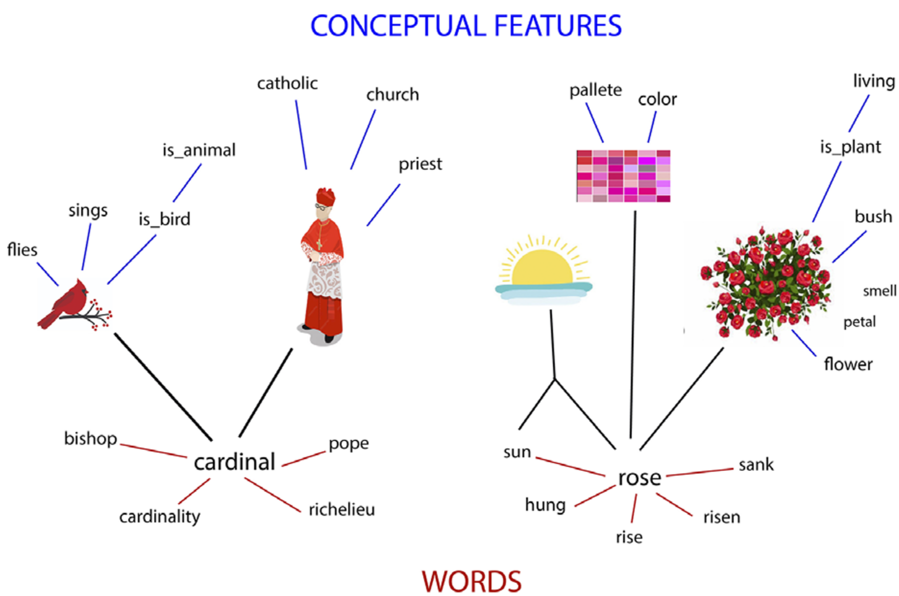

Figure 1. Schematic representation of conceptual features and their links to words within semantic memory. Features may temporarily cluster together into concepts and relate to others in a context-dependent fashion, such as when interpreting ambiguous words. Words may have associative links to conceptual features and other words or linguistic structures.

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language learning and usage in multi-sensory contexts strengthen the association between words and sensorimotor features in semantic memory.

Multiple neurocognitive studies have shown that words activate brain regions recruited for action or perception (Martin & Chao, 2001; Pulvermüller, 2005). For example, *kick, pick* and *lick* verbs activate premotor regions associated with leg, hand or mouth actions. Even motor features resulting from sentential composition appear to recruit motor-related regions. For example, *pushing the piano* elicits stronger activity than *pushing the chair* or *forgetting the piano* (Moody & Gennari, 2010). As argued by models of semantic cognition, action or perception networks may be co-activated with language-processing regions computing context-dependent interpretations (Hoffman et al., 2017; Lambon Ralph et al., 2017), suggesting that computing linguistic meaning is distinct from but overlaps with semantic memory networks.

Experience-based approaches to cognition are consistent with the possibility that people from different cultures and languages may recruit different associated features in semantic memory (Kemmerer, 2023). Group differences could emerge from learning different systems that map verbal expressions to semantic memory features. For example, different languages employ distinct constructions and morphological resources to describe the same picture, indicating variations in mapping a conceptual representation into verbal expressions (Gennari et al., 2012; Papafragou et al., 2002). Some authors argue that word order sequencing in language is akin to learned procedures in procedural memory (Hamrick et al., 2018; Ullman, 2016), which entails procedural memory differences across languages with distinct sequencing patterns. Likewise, languages differ in how words map into sensory experiences, such as colour perception, implying that words from different languages activate distinct semantic-memory features (Regier & Kay, 2009). Thus, cross-linguistic differences may lead to contrasting associations in semantic or procedural memory, with some languages and cultures more readily activating certain features or patterns than others.

Many cross-cultural studies are consistent with this possibility. Growing up in different cultures modulates how people inspect scenes (Chua et al., 2005; Flecken et al., 2014), how they reason about the world (Atran et al., 2005; Ojalehto & Medin, 2015) or how they respond to nameable colours (Thierry et al., 2009). For example, in oddball tasks where participants respond to shapes, speakers with contrasting names for the colour stimuli show different event-related potentials from speakers who lack the naming distinction (Thierry et al., 2009). In another study, Korean speakers who consistently distinguish different containment relationships between objects (tight vs loose fit) are more susceptible than English speakers to attentional capture by visual fitness features in colour tasks (Goller et al., 2020). These examples suggest that frequent references to visual features may increase the likelihood of attending to these features or verbal references, leading to cross-linguistic differences.

However, one's semantic associative network is not necessarily stable over time or entirely available at any time. Individuals continuously learn from experience, and new experiences can potentially change one's semantic network. Learning to navigate a new city or learning a new language can lead to slow semantic reorganisation through memory consolidation – a process integrating episodic experiences with existing semantic knowledge (Dudai, 2012; James et al., 2017). Moreover, contextual features may increase the availability of some cognitive representations more than others, as in semantic or associative priming (McNorgan et al., 2011;

Thompson-Schill et al., 1998). For example, when we sit back and listen to language in visual scene contexts, words and phrases spontaneously drive attention to semantically related but unnamed visual objects (e.g., looking at a trumpet when hearing *piano*) (Altmann & Mirković, 2009; Huettig & Altmann, 2005; Kamide et al., 2003; Spivey et al., 2002; Tanenhaus et al., 1995). Finally, we entertain mostly relevant semantic information when pursuing specific goals. For example, when searching for our house keys, we must retrieve relevant memories (where we left them or are likely to have left them) while representing object features capable of identifying the keys in the current search environment (visual vs tactile search in our pockets). Thus, our action goals and contexts constrain the semantic memory representations recruited in a specific situation.

These observations suggest that although speakers of different languages may vary in their semantic associative networks and verbal practices, in most laboratory studies and ordinary goal-oriented tasks, contextual features, intended goals or task demands will constrain the cognitive representations entertained and the extent to which linguistic meaning is recruited. Attuning to contextual conditions is a key characteristic of adult human cognition, enabling successful performance in a multi-faceted and dynamic world.

2. Language and cognition in action

A critical feature of goal-directed behaviour is that attention is focused on the contextual features consistent with the internal goal representation (Barsalou, 1999; Hommel, 2022; Hommel et al., 2001). Different task goals can therefore elicit distinct processing of the same stimuli. For example, watching an animation to describe it elicits a different pattern of fixations from watching it for other purposes (Papafragou et al., 2008; Sakarias & Flecken, 2019). Likewise, providing form-based or meaning-based word judgements directs attention to different stimulus aspects, resulting in differential stimulus recollection (Craik & Tulving, 1975). Even salient stimulus characteristics can be missed when participants are engaged in goal-directed visual processing. For example, when counting the number of ball passes between players in a video, the presence of a gorilla among the players is often unnoticed (Simons, 2000). Thus, visual attention oriented to action is typically *selective*, with observers attending to goal-relevant features more than goal-irrelevant ones (Hommel et al., 2001).

Goal-oriented action may require additional processes when tasks admit alternative responses or procedures to accomplish them. In these cases, competition or weighting mechanisms may intervene to choose one alternative over another within the allocated time (Allen et al., 2010; Botvinick & Cohen, 2014; Hommel, 2022; Kool et al., 2010; Shenhav et al., 2017). For instance, when naming an action performed with a visually presented object (e.g., a door or scissors), the conflict between two equally likely alternatives (e.g., *open* and *close*) elicits longer reaction times than having one dominant alternative (e.g., *cut*). When alternative task procedures are available, processes are often argued to yield the optimal, less costly response to the task's demands. For example, selecting among alternative courses of action may depend on perceived cognitive effort, i.e., selecting the action or response expected to incur the least mental effort within the available resources (Shah & Oppenheimer, 2008; Shenhav et al., 2017).

Accommodation of external demands using available internal resources is particularly important in tasks involving open-ended judgements, such as questions or decisions that do not require objective accuracy or specify a clear decision criterion. For this reason, much of decision-making research has focused on cognitive shortcuts or heuristics that minimise cognitive effort. For example, when asked which of two unrelated events, A or B, is more likely, people choose the event with more available (easily accessible) event instances – a heuristic known as the availability heuristic (Tversky & Kahneman, 1973). In Bayesian accounts, heuristics are modelled as probabilistic inferences based on available information, including stimuli, prior knowledge and recent contextual experience (Chater et al., 2006; Oaksford & Chater, 2020; Shah & Oppenheimer, 2008).

These brief observations suggest that goal-oriented action is constrained by the relationship between contextual characteristics and task demands, and these constraints may determine which available features of semantic memory are temporarily activated in a specific situation. These contextual constraints operate as modulatory forces dynamically interacting during processing, as argued by most approaches to cognition, including embodied, connectionist and dynamic theories (Hoffman et al., 2017; Spivey, 2008, 2023). Therefore, an interactive view of cognition implies that language may play different roles depending on how and when linguistic information contributes to achieving a goal within the current context and available resources. In theories of cognition, the management of mental representations oriented towards behaviour is variably referred to as *working memory* and *executive*, *domain-general* or *cognitive control* processes and is typically associated with frontal brain regions (Baddeley, 2003; Badre, 2025; Braver, 2012). A common characteristic of executive or control processes is that they converge in optimal solutions within the available task contexts and limited cognitive resources (Lieder & Griffiths, 2020).

In what follows, I review previous findings exemplifying potential linguistic contributions to these cognitive processes, such as goal-directed representations and attuning to task demands. Reframing earlier studies in these terms illustrates how task and goal representations constrain and even determine the role of language in non-verbal tasks.

2.1. Task–goal representations in experimental contexts

As semantic memory contains interconnected linguistic meaning and multi-sensory conceptual structures (cf. Figure 1), a task requiring concurrent or temporally contiguous visual and linguistic stimuli will activate semantic features associated with both stimulus types. Yet, how these features affect behavioural performance depends on goal representations. The role of task goals can be inferred from the studies demonstrating that words and sentences may either facilitate or interfere with perceptual tasks such as visual object recognition (Estes et al., 2008; Lupyan et al., 2020; Spivey et al., 2001; Stanfield & Zwaan, 2001; Zwaan et al., 2002; Zwaan & Taylor, 2006). When the words' semantic features overlap with the conceptual features recruited for task performance, e.g., object identification, performance is facilitated via spreading activation through the semantic network. Interference or response delays, on the other hand, may occur when the words' features conflict with those recruited to achieve the task goal. For example, processing words containing incongruent features with a target may delay target identification. For more details on the temporal dynamics during processing, see S. E. Anderson et al. (2011) and Connell and Lynott (2012).

In memory studies, the stimulus structure or the experimental design may facilitate or hamper goal attainment. For example, verbal categorisation during learning may produce contrasting results in later visual-recognition tests. Studies examining object or scene recognition as a function of learning tasks, e.g., comparing a linguistic task to a non-linguistic task, have found that visual memory performance was poorer after linguistic categorisation tasks (Carmichael et al., 1932; Feist & Gentner, 2007; Lupyan, 2008). These results align with an interactive encoding account, whereby language use during learning distorts object representations towards typical category features, resulting in poorer recognition or discrimination (Feist & Gentner, 2007; Lupyan, 2008).

Other studies, in contrast, have shown better, rather than poorer, recognition memory with language use. They demonstrate that language production or comprehension during stimulus exposure may lead to better memory performance than non-verbal tasks (Huff & Schwan, 2008; Lupyan et al., 2007; Richler et al., 2011, 2013; Sakarias & Flecken, 2019). Richler et al. (2013) argued that memory facilitation results from verbal cues making the stimuli more memorable and distinctive. A key difference between these and Lupyan's (2008) studies was the structure of the stimulus set so that naming facilitated subsequent recognition memory when the labels uniquely identified an object of a given category (lamps, cups, chairs, etc.), i.e., the labels help diagnose whether a specific object was previously seen. In contrast, category labels hinder subsequent recognition when many similar objects share the same label during learning, causing exemplars of a category to resemble one another due to their similarity to the category prototype. Therefore, stimulus features and labels operate differently within contrasting stimulus sets and experimental designs (e.g., numbers of exemplars in a category). What matters in visual-recognition tasks is whether stimulus features help identify and discriminate an item from the set of studied stimuli. See Wang et al. (2024) for a comparison of task instructions across the same experimental designs and Wang & Gennari (2019) for language-mediated retrieval effects.

Together, these perceptual and memory studies suggest that the relationship between the task goal and the experimental context determines how verbal labels modulate performance.

2.2. Optimising task performance with internally available words

Experience-based accounts of semantic memory are compatible with robust links between words and conceptual structures, particularly those that are frequently strengthened through everyday communication and practice. Therefore, verbal expressions may be spontaneously recruited to aid task performance. For example, verbal expressions can provide shorthand substitutes for complex non-verbal representations or those needing to be mentally retained or manipulated further. In many ordinary tasks, people use language to encode information, e.g., when memorising a phone number, calculating sums or studying for an exam. As suggested by research on inner speech, people may also reason or plan complex actions by talking to themselves or writing to-do lists (Alderson-Day & Fernyhough, 2015; Fernyhough & Borghi, 2023). A recent meta-analysis of verbal interference in dual-task paradigms

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indeed suggests that complex cognitive tasks, such as reasoning, mental calculations and behavioural self-cuing (e.g., task reminders), involve some form of inner speech (Nedergaard et al., 2022).

This suggestion is consistent with many studies demonstrating distinctive behaviours across and within language groups. Object names, for example, are spontaneously recruited in visual search tasks in monolingual speakers (Meyer et al., 2007; Walenchok et al., 2016). In bilinguals, English and Spanish speakers fixate on different objects in a display while searching for a clock in Figure 2: English speakers fixate on an English phonological competitor (e.g., clouds), whereas Spanish speakers fixate on a Spanish phonological competitor (e.g., fixating on a gift [Spanish 'regalo'], when searching for a clock (Spanish 'reloj') (Chabal & Marian, 2015). The competitors' activation in these studies may depend on name accessibility (familiar objects prime their high-frequency names) and the requirement to maintain the object in working memory for an upcoming visual search.

Having readily available names also facilitates colour discrimination. For example, speakers possessing linguistic categories for colour stimuli are faster at discriminating them than speakers lacking those categories unless task demands prevent lexical access (Gilbert et al., 2005; Lupyan et al., 2020; Winawer et al., 2007). In some colour discrimination tasks, performance would be strenuous without linguistic aid. These studies, for example, asked speakers of different languages to retain a colour shade for 30 seconds and later indicate which shade was seen from two similar ones (Davidoff et al., 1999; Roberson et al., 2005). The alternatives straddled name boundaries in one language or another. Participants may naturally resort to colour names to facilitate encoding and discrimination in these contexts, as decisions for colours with the same or different names are readily apparent.

Resorting to names in the colour domain is magnified by the continuous nature of the stimulus. Indeed, individual stimuli drawn from continuous domains, such as colour, time and spatial distance, are difficult, if not impossible, to retain in memory because our brain does not encode these domains in the metrics conventionally used to measure them (e.g., hue, saturation and intensity values for colours). For this reason, Bayesian approaches to cognition have argued that retrieving individual stimuli from continuous domains can be explained by probabilistic inferences (Huttenlocher et al., 1990, 1991, 2000; Regier & Xu, 2017; Shi et al., 2013). In memory-based colour discrimination tasks, uncertainty about which colour shade was previously seen leads participants to combine prior knowledge – the linguistic category – with the stimulus memory to infer the most likely seen colour from the

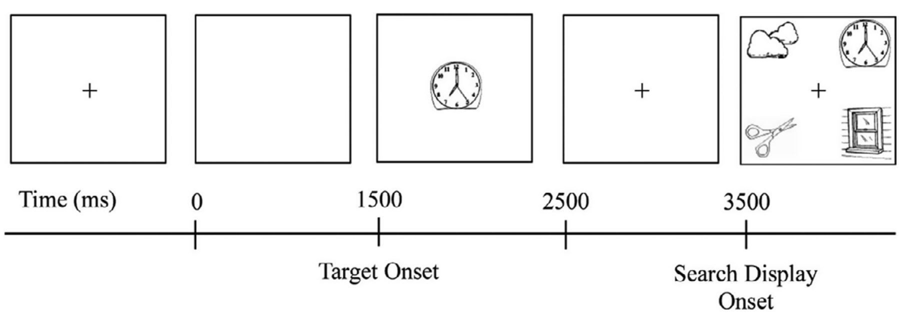

Figure 2. Task structure of the visual search task in Chabal and Marian (2015).

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presented alternatives (Cibelli et al., 2016). This inference is argued to operate across and within a language. For example, when participants are instructed to pinpoint a previously seen colour in a continuous colour wheel, probabilistic inferences lead to responses biased towards typical category members. Likewise, the recollection of object sizes involves inferences from category-based prior knowledge, resulting in biased recollection towards typical object sizes (Hemmer & Steyvers, 2009a, 2009b; Steyvers & Hemmer, 2012).

These examples indicate that response uncertainty and expected difficulty may encourage spontaneous language recruitment. As language is not necessarily recruited in all visual tasks, spontaneously resorting to language may depend on the convergence of contextual factors, such as stimulus properties, task goals and response uncertainty. For example, words would not be recruited if visual stimuli did not have standard names available. Likewise, inferences or covert naming may be unnecessary if task responses are easily determined. Thus, the role of language in cognitive tasks depends on how well it serves the processes involved in achieving the task goal.

2.3. Optimising performance with contextually available language

Semantic memory features or structures that have been processed recently within the experimental context remain more available for further use than structures that have not been recently used – a phenomenon often referred to as implicit priming or learning. For example, many lexical and syntactic priming studies show persistent reuse of words or structures across multiple intervening events or tasks without explicit recollection (Bock et al., 2007; Chang et al., 2006, 2012; Schacter, 1990). It follows that language use in the experimental context may modulate task performance *at a distance*, i.e., when language is not temporally contiguous with visual stimuli.

This possibility has been demonstrated in tasks involving decision-making with indeterminate responses, such as selecting an item among similar alternatives. A cross-linguistic study manipulated the task that preceded a similarity judgement task. Participants had to choose which of two manner or path alternatives was most similar to a target event. Similarity choices were aligned with linguistic meaning (path alternatives in Spanish) only when a description rather than a non-verbal task preceded the similarity judgements (Gennari et al., 2002). This result suggests that the linguistic context primed linguistic meanings and made them available to aid or support subsequent similarity choices. In Bayesian inference terms, verbal expressions become part of the priors – the contextually available information to infer responses – resulting in response biases towards linguistic meanings. Nevertheless, it remains unclear whether these biases arise spontaneously from the network's activation dynamics when facing uncertainty or whether they are strategically (deliberately) controlled.

Interestingly, similar contextual language modulations have been observed in bilinguals, where similarity choices or sorting decisions are consistent with the language of the experimental context (Athanasopoulos et al., 2015; Kersten et al., 2010). Semantic memory in bilinguals is the subject of intense study (Heredia & Altarriba, 2014). However, a crude approximation to the observations in section 1 is that words from the two spoken languages will be associated with potentially distinct

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sets of conceptual features. Critically, words and linguistic structures in bilinguals are also linked to contrasting learning experiences, memories and practices that using each language throughout life entails. Indeed, bilingual studies have shown that language use can prime cultural values, practices and autobiographical memories experienced in that language (Akkermans et al., 2010; Chen & Bond, 2007, 2010; Holtgraves et al., 2014; Marian & Kaushanskaya, 2007). Thus, using one or another language in the experimental context may increase the availability of words and knowledge schemas associated with the language of the context, supporting subsequent decisions. Nevertheless, control processes in bilinguals are a topic of active research, so other high-order influences may occur (Bialystok, 2017; Filipović & Hawkins, 2019; Green & Abutalebi, 2013).

In continuous domains with few known or nameable categories, such as spatial location and duration, uncertainty in judging or reproducing the precise stimulus duration, distance or location leads to probabilistic inferences based on relevant available knowledge. Many studies have shown, for example, that judging the duration of tones one after another is modulated by the tone duration of previous trials, as participants implicitly compare current and preceding stimuli. Across multiple trials, this comparison results in temporal judgements biased towards the overall stimulus average, a phenomenon referred to as central tendency effects (Jazayeri & Shadlen, 2010; Shi et al., 2013). Similar results have been reported for judgements of spatial locations, where averaged locations or coarse representations relative to known categories guide performance (Gudde et al., 2016; Huttenlocher et al., 1990, 1991, 2000; Tompary & Thompson-Schill, 2021). These results suggest that continuous stimulus domains might be particularly susceptible to inferences based on contextually available information, either prior categorical (linguistic) knowledge or recent stimulus experience. From this observation, it follows that contextually available linguistic stimuli have the potential to modulate temporal or spatial judgements, as shown in some studies (Bylund & Athanasopoulos, 2017; Casasanto, 2016).

The availability of linguistic labels or nameable features from prior experience has been extensively studied in category learning (Brojde et al., 2011; Lupyan et al., 2007; Vong et al., 2016; Zettersten & Lupyan, 2020). These studies have examined various stimulus types and task designs, including meaningful and non-meaningful labels for visual stimuli. Some of these studies suggest that categories with nameable features are learned more quickly and that this learning depends on stimulus features and prior linguistic experience. For instance, object shapes are inherently more nameable based on linguistic experience than object textures (Brojde et al., 2011). Other studies have shown that colour or shape categories containing easier-to-name features are learned more effectively than those with harder-to-name features (Zettersten & Lupyan, 2020). These findings suggest that prior verbal experience makes category learning (an instance of goal-oriented behaviour) more efficient and highlight promising avenues for exploring cross-linguistic variations in feature naming patterns.

3. Discussion

This brief review highlighted some operating principles of goal-directed action and decisions based on semantic knowledge, suggesting that higher-order cognitive

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processes may govern the interaction of linguistic and non-linguistic representations. Section 1 introduced the role of prior knowledge in supporting cognitive processes and suggested that verbal expressions become associated with conceptual features or structures through experience-based learning. This view is compatible with different languages establishing distinctive links to conceptual structures and leading to contrastive attentional patterns or cognitive representations. Nevertheless, cross-linguistic vocabulary or lexicalisation differences do not necessarily entail distinct cognitive representations beyond contrasting linguistic meanings. The semantic features that words and linguistic patterns bundle together during language use do not need to operate together in cognitive tasks outside of language use. In many respects, non-verbal representations are similar across languages despite linguistic differences because the physical world is largely shared, and its regularities are similarly learned (Malt et al., 2003, 2008; Papafragou et al., 2002; Ünal et al., 2021).

Section 2 discussed how task goals, contexts and demands constrain the role of language in an experimental task. In studies involving linguistic and visual stimuli, such as those in section 2.1, the relationship between task goals and experimental contexts determines performance. Similarly, internally available verbal expressions can be recruited to expedite processing or enable further cognitive operations, such as visual search, colour discrimination or decisions (see section 2.2). Language use within the experimental context may encourage (or implicitly prime) resorting to linguistic meanings to facilitate other processes, such as decision-making or learning (see section 2.3). Resorting to language may thus depend on the convergence or interaction of context and stimulus properties, task goals and processing demands.

Generally, the adult cognitive system responds to experimental goals as efficiently as possible within the constraints of internal and contextually available representations and resources. Rather than viewing language as the driving force behind language effects, this perspective presents language as a resource for other cognitive processes oriented towards a goal within a constraining context. Language may intervene in a non-verbal task because domain-general cognitive processes promote its recruitment. Several computationally explicit theories support these goal-oriented processes, although they differ in their target level of explanation. Interactive connectionist and constraint satisfaction models aim to elucidate processing mechanisms, while Bayesian accounts strive to establish general cognitive principles independently of their mechanistic implementation (Chater et al., 2006; Jones & Love, 2011; McClelland et al., 2014). Based on these models, I have argued that previous findings demonstrating language modulations in non-verbal tasks exemplify the operation of these cognitive principles.

Nevertheless, specifying the structure and inner workings of the cognitive processes that guide behaviour is not simple. Multiple working memory, control and executive function theories have been proposed to explain cognition, which differ in the cognitive architectures assumed and the extent to which they mimic brain structure and mechanisms (Baddeley, 2012; Botvinick et al., 2001; Botvinick & Cohen, 2014; Miyake & Friedman, 2012; Shenhav et al., 2017; Van Ede & Nobre, 2025). Most theories assume some form of working memory as a system or network that temporarily holds and manipulates long-term representations. The information currently active in working memory is selected to fulfil one's goals and may flexibly draw on different sources of available knowledge or accessible features, as schematically represented in Figure 3. Various processes have been proposed to occur within

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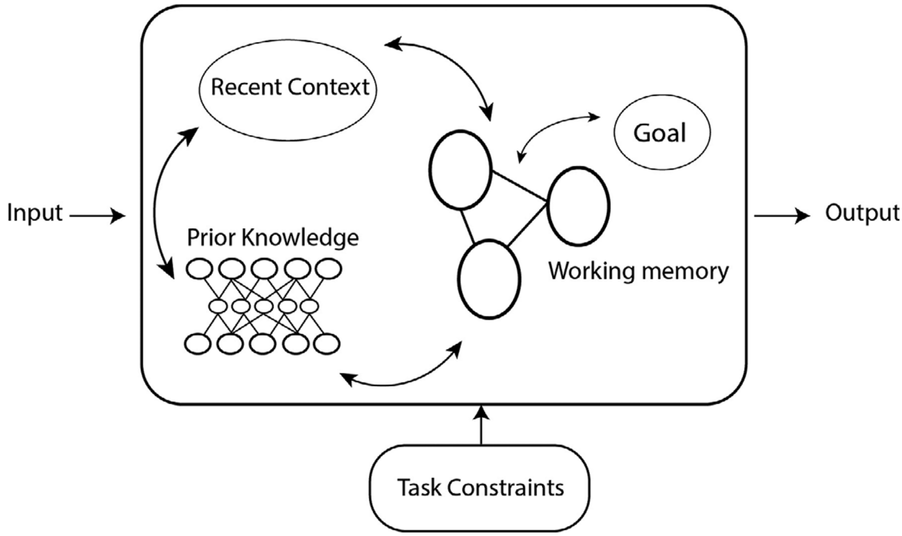

Figure 3. Schematic representations of resources and a goal representation interacting within working memory, and modulated by external task constraints (e.g., stimulus structure, speed or accuracy demands).

working memory, including information maintenance, selection and several types of conflict resolution and prioritisation processes (e.g., those dealing with dual-task goals, competing stimulus features, cues or responses). Ultimately, contextual constraints, such as the nature of the task, the stimuli and the experimental context, will modulate the relative reliance on one resource over another or how a specific task is performed.

For language–cognition interactions, it remains to be determined which cognitive tasks, stimuli or experimental contexts are more conducive to spontaneous or primed language recruitment. For example, Bayesian approaches suggest that tasks with indeterminate responses may be more likely to rely on prior linguistic and conceptual knowledge. Yet, systematic comparisons across decision and stimulus types are scarce. Likewise, it is unclear whether resorting to language knowledge, such as word meanings or stimulus names, is under conscious control or is rather implicit. These issues are not confined to language and cognition research but extend to other areas of cognitive research. The proliferation of increasingly specialised research fields in working memory, decision-making, attention or cognitive control makes it challenging to infer general cognitive mechanisms. In this respect, the Whorfian question presents a unique opportunity to continue concerted efforts to explore the tasks, contextual features and linguistic experiences that lead to one outcome or another.

From an experimental perspective, progress in understanding language–cognition interactions necessitates the development of higher-order theories that predict how and when verbal knowledge or experience serves task goals or permeates cognitive activities. Systematic hypothesis testing across tasks, stimulus types or contexts will enhance our understanding of how and why linguistic information modulates cognitive representations and, most importantly, elucidate why some tasks, and not others, exhibit verbal influences.

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