Lund eye tracking studies in research on language and cognition

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ABSTRACT: The research group from Humanities Laboratory at Lund University, Sweden, presents three strands of research on language and cognition where eye-tracking methodology has been used as a window on the mind. The paper includes: (1) eye tracking studies on picture viewing and picture description showing the dynamics of how speakers perceive, conceptualize and spontaneously describe complex visual scenes on higher levels of discourse, (2) studies using a combination of eye tracking and spoken scene descriptions to study mental imagery and to track the ability of "seeing something in the mind's eye", and (3) eye tracking studies conducted in order to study "thinking for speaking" and linguistic diversity by investigating language-specific cognitive effects. The paper ends with a visionary outlook for future applications of eye tracking methodology in the study of language and cognition.

Key words: eye tracking methodology, language and cognition, visual attention, cognitive semantics, mental imagery, thinking for speaking, event perception, event description, manner of motion

It is, of course, impossible to d i r e c t l y uncover the content of our minds. If we want to learn about how the mind works, we have to do it indirectly, via o v e r t m a n i f e s t a t i o n s. The research group from Lund University, Sweden, has studied language and cognition with the help of eye tracking methodology in combination with spoken language descriptions. Eye movements reflect human thought processes and offer us a window to the mind. Spoken language descriptions are linguistic expressions of a focus of conscious attention and offer us another window on the mind. Both kinds of data can be used as an indirect source to gain insights about the underlying cognitive processes.

In this paper, we present results from a number of studies conducted at the Humanities Laboratory at Lund University. The presented studies include eye tracking studies on picture viewing and picture description where a multimodal scoring method was used to study mental processes (section 1), eye tracking studies on mental imagery suggesting that informants create a sort of mental image as an aid for their spoken descriptions from memory (section 2) and eye tracking studies on "thinking for speaking" showing how speakers distribute their visual attention during event description and event perception (section 3). Finally, we mention future application of eye tracking methodology within the Linneaus Centrum for Communication, Cognition and Learning and the long-term project "Thinking in Time" (section 4).

1 Picture viewing and picture description: two windows to the mind

In her studies on picture viewing and picture description, Holšánová (2001, 2006, 2008, cf. also Šlédrová 2004) investigated how speakers perceive, conceptualize and

spontaneously describe complex pictures on higher levels of discourse. She used eye tracking methodology along with verbal protocols and a multimodal scoring method to study the underlying mental processes. Spoken language protocol in combination with an eye tracking protocol help us to reveal which features observers are focusing on. Let us look at the relation between the visual and the verbal focus in the following example: '*In front of the tree which is curved is a stone'* (in the Swedish original: *framför trädet som är böjt finns en sten*).

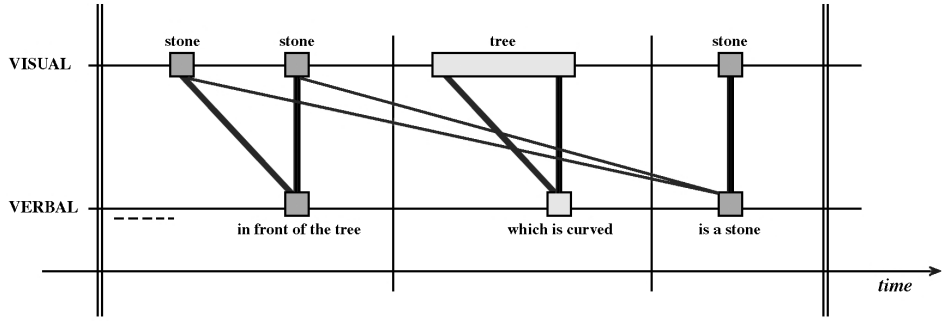

Figure 1: '*In front of the tree which is curved is a stone'* (from Holšánová 2008:110)

With the help of the multimodal scoring method (Holšánová 2001), we synchronized complex ideas formulated during the descriptive discourse (verbal stream) with fixation patterns collected during the visual inspection of a complex picture (visual stream). The contents of the "attentional spotlights" in picture viewing and picture description were then compared and the clusters in the visual and verbal flow were extracted. In the visual stream in figure 1, the object 'stone' is fixated three times). If we compare these congurations with the verbal stream, we discover that the relation between the visual and the verbal focus is different. While their relation is one of semantic identity in the third configuration (*stone = stone*), this is not the case in the first "triangle" configuration. Here, the concrete object 'stone' is viewed from another perspective since the focus is not on the object itself, but rather on its location (*stone = in front of the tree*). In the "triangle" configuration, there is an indirect semantic relation: The observers' eyes are "pointing" at a concrete object in the scene but – as can be revealed from the verbal description – the observer is mentally zooming out and focusing on the p o s i t i o n of the object.

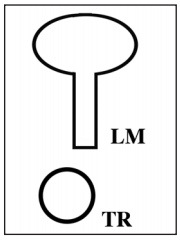

Figure 2: '*In front of a tree*' (stone = trajector, tree = landmark) (from Holšánová 2008:127)

This latter relation can be compared with image schemata and the figure-ground (trajector-landmark) relation in cognitive semantics (Holmqvist 1993, Johnson 1987,

Langacker 1987, Lakoff 1987). For instance, in the relation 'in front of', the trajector (TR) – the location of the object – is considered to be the most salient element and should thus be focused by the observer/describer (cf. Figure 2). In fact, when saying *'in front of the tree'*, the informant actually looks at the trajector (= stone) and directs his visual attention to it. In other words, the saliency in the TR role of the schema co-occurs with the visual (and mental) focus on the stone, while the stone itself is verbalised much later. It would be interesting to conduct new experiments in order to verify this finding from spontaneous picture description for other relations within cognitive semantics. This example also shows that much could be gained by introducing the theoretical concepts from cognitive semantics, such as landmark, trajector, container, prototype, figure-ground, source-goal, centre-periphery, image schema etc. as explanatory devices for studying concepts of human cognition on a dynamic, processual level.

The combination of visual and verbal data revealed how picture objects are focused on and conceptualized at different levels of specificity (Holšánová 2008). The multimodal scoring method was used to investigate temporal and semantic correspondences in visual and verbal data. Concerning t e m p o r a l r e l a t i o n s, we found that the verbal and the visual signals were not always simultaneous. The visual focus was often ahead of speech production. This latency was due to conceptualisation, planning and formulation of a free picture description on a discourse level. Visual focus could, however, also follow speech (i.e. a visual fixation cluster on an object could appear after the describer had mentioned it). In these cases, the describer was monitoring and checking his statement against the visual account. In some instances, there was temporal simultaneity between the verbal and visual signals but no semantic correspondence (when informants – during a current verbal focus – directed preparatory glances towards objects to be described later on). Some of the inspected objects were not mentioned at all in the verbal description, some of them were not labelled as a discrete entity but instead included later, on a higher level of abstraction. Also, areas and objects were frequently re-examined and a re-fixation on one and the same object could be associated with different ideas.

We found that the s e m a n t i c r e l a t i o n s between the objects focused on visually and described verbally were often implicit or inferred. They varied between object-object, object-location, object-path, object-activity and object-attribute. We could witness a process of stepwise specification, evaluation, interpretation and re-conceptualisation of picture elements and of the picture as a whole. We saw a gradual dissociation between the visual representations in the scene and the discourse-mediated mental representations built up in the course of the description. During their successive picture discovery, informants described not only scene-inherent objects with spatial proximity but also clustered elements distributed across the scene and created new mental groupings based on abstract concepts. The process of mental zooming in and out could be documented, where concrete objects were re-fixated and viewed with another concept in mind. A priming study showed that the eye movement patterns con-

nected to abstract concepts were not restricted to the process of planning and structuring a verbal description of the scene, but rather, are connected to the scene semantics. Similar viewing patterns could be elicited by using utterances from the original picture description even with a group of listeners. In sum, the comparison of visual and verbal foci in the process of picture viewing and picture description showed us the ways information is acquired and processed in the human mind (Holšánová 2008).

2 Using eye tracking and spoken descriptions to study mental imagery

It is sometimes argued that we do not visualise, at least not in general, when we understand language. As long as the answer to this question depends on introspective observation, the matter cannot be objectively settled. With eye tracking methodology, these different types of inner visualisation processes can be exactly traced and revealed. M e n t a l i m a g e r y has been described as "the mental invention or recreation of an experience that in at least some respects resembles the experience of actually perceiving an object or an event, either in conjunction with, or in the absence of, direct sensory stimulation" (Finke 1989: 2). In popular terms, mental imagery is described as "visualising" or "seeing something in the mind's eye". We use mental imagery when we, for example, mentally recreate personal experiences from the past, retrieve information about physical properties and relationships, read novels, plan future events, imagine transformations by mental rotation and mental animation and when we solve problems (e.g. Finke 1989, Hegarty 1992, Yoon & Narayanan 2004, Kosslyn, Thompson & Ganis 2006). In other words, imagery plays an important role in memory, planning, and visual-spatial reasoning, and is considered a central component of our thinking.

Since mental images are closely connected to visual perception, this mental invention or re-creation of experience has been found to almost always result in observable eye movements. Eye tracking has become a very important tool in the study of human cognition, and current research has found a close relation between eye movements and mental imagery (Brandt & Stark 1997, Holšánová, Hedberg & Nilsson 1999, Laeng & Teodorescu 2001, Spivey & Geng 2001). In order to verify the assumption that we use our ability to create pictures in our minds, we conducted a series of studies on mental imagery where participants looked at a blank white board and visualized a scene they had previously either seen on a picture or heard as a spoken scene description (Johansson, Holsanova & Holmqvist 2005, 2006).

The descriptions of a complex scene were transcribed in order to analyse w h i c h picture elements were mentioned and w h e n. We developed a method for measuring spatial and temporal correspondence and the eye movements were then analysed according to objects derived from the descriptions. For instance, when an informant formulated the following ideas,

01:20 – And ehhh to the **left** in the picture'
01:23 – there are large **daffodils,**
01:26 – it looks like there were also some **animals there** perhaps,

we expected the informant to move her eyes towards the left part of the white screen during the first focus. Then it would be plausible to inspect the referent of the second focus (the daffodils). Finally, we could expect the informant to dwell for some time within the daffodil area – on the white screen – searching for the animals (three birds, in fact) that were sitting there on the stimulus picture. When analyzing the data, a significant similarity was found between the eye movement patterns during picture viewing and those produced during picture description. Figure 3 shows one participant's eye movements after an inspection of the picture (left, 30 sec.) and after an oral description of it while looking at the blank white board (right, 98 sec.).

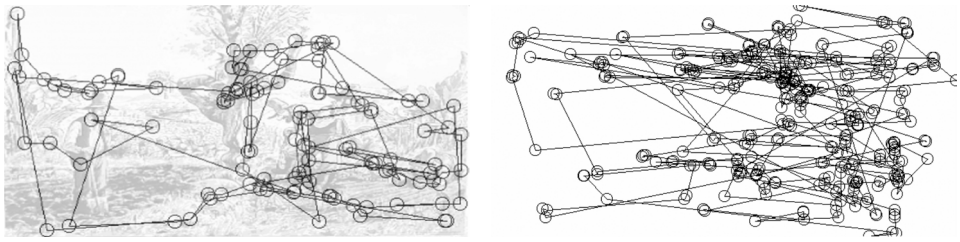

Figure 3: Eye movement patterns for one participant after viewing the picture and after visualizing it in an oral description from memory while looking at the white blank board

The results of our studies clearly showed that when describing a scene from memory the participants to a high degree moved their eyes in a pattern that "painted" the imagined scene on the white board in front of them. Additionally, it was found that the effect was equally strong irrespective of whether the original elicitation was spoken or visual.

Our results can be interpreted as further evidence that eye movements play a functional role in visual mental imagery and that eye movements indeed are stored as spatial indexes that are used to arrange the different parts correctly when a mental image is generated. An alternative account is the "perceptual activity theory" (Thomas 1999) suggesting that instead of storing images, we store a continually updated and refined set of procedures or schemas that s p e c i f y h o w t o d i r e c t o u r a t t e n t i o n o u t in different situations. In this view, a perceptual experience consists of an ongoing, schema-guided perceptual exploration of the environment. Imagery is then the r e - e n a c t m e n t of the specific exploratory perceptual behaviour that would be appropriate for exploring the imagined object as if it were actually present.

There is, however, another alternative interpretation. Researchers within the "embodied" view claim that instead of relying on a mental image, we use features in the external environment. An imagined scene can then be projected over those external features, and any storing of the whole scene internally would be unnecessary. Ballard, Hayhoe, Pook & Rao (1997) suggest that informants leave behind "deictic pointers" to locations of the scene in the environment, which later may be perceptually accessed when needed. Pylyshyn (2002) has developed a somewhat similar approach to support propositional representations and speaks about "visual indexes" (cf. also Spivey, Tyler, Richard-

son & Young 2000). Such an association with the external world would assume no mental images, only the binding of active memory objects to real objects. Consequently, the eyes would just move to that position in the real world that was associated to the current propositional object.

However, Johansson, Holsanova & Holmqvist (2005, 2006) replicated their experiments in complete darkness (without any possible external visual features) where associations from memory objects to positions in the external visual world would be impossible. The results strongly showed that the eye movement effect was still present. We therefore argue that they indeed do reflect spatial positions from mental images.

Nevertheless, the next challenging question becomes h o w, w h e n and w h y imagery representations are used. What types of concepts actually do trigger mental models of spatiality? When are image representations favoured over linguistic representations? Can eye tracking be used as a method to answer questions of these types? In a recent study of time statements conducted at the Humanities Laboratory in Lund (Polunin, Holmqvist & Johansson 2008), it was reported that eye movements correspond with the movement along a time line. For example, participants who imagined an event that happened last week moved their eyes further to the left on a "mental time line" and further to the right when they imagined an event that was supposed to happen in the future.

The findings described above have implications for learning. For speakers and listeners, both mental imagery and re-enactment of events can play an important role as a memory aid (Holsanova, Johansson & Holmqvist 2008). In the future, we plan to conduct several eye tracking studies that examine how and when image representations are used. For example, how they are related to metaphorical language, problem solving and also what happens in situations where we visualize dynamic scenes with animations.

3 Thinking for speaking, linguistic diversity and visual attention

Research in linguistic relativity, the idea that the language we use influences our thinking, has yielded interesting and thought-provoking results. Our language seems to correlate with, for example, spatial abilities (Levinson 2003) and event perception (Slobin 2004). Typically, empirical research in linguistic relativity involves first selecting one particular aspect of language that differs between two or more languages. Then, the aim is to observe differences in other n o n - l i n g u i s t i c c o g n i t i v e f u n c t i o n s and how these differences are predicted by the language differences. For example, we observe that speakers of Tzeltal (Brown 2004) have a language rich in body-positionals, allowing the speakers to utter distinct descriptions such as (Slobin 2004).

(1) *jipot **jawal** ta lum*
'He [the boy] has been thrown **lying_face-upwards_spread-eagled** to the ground.'

We might then move on to predict that in order to make such detailed descriptions, the speakers must pay relatively more attention to the particular body position of an object

in order to describe it – at least relatively more attention than a speaker of a less positional-rich language, such as English or Swedish. The last step is, then, to measure actual differences in attentional distribution.

However, results are often mixed, and suggest that the actual task involved plays a great role whether the cognitive differences can be found or not. It seems that language-driven effects do not show when the tasks are purely non-linguistic, but as soon as language is involved in some form, the effects appear (see e.g. Zlatev, Blomberg & David 2010). Slobin suggested that in order for language to have a chance to influence our thinking, the experiment needs to allow language to enter the task in some way. Describing an event would be such an approach, where the different levels of encodability between languages would be able to influence the linguistic production results. Thus, "thinking for speaking" (Slobin 1996), would be different from thinking for some other non-linguistic task, with regards to the ability to perceive language-driven cognitive effects. This raises questions about the nature of these correlations, how we determine causal relationships, as well as h o w this is possible at all.

One start to elucidate the thinking for speaking process would be to actually see how we distribute our visual attention during a linguistic task with visual stimuli compared to a similar but non-linguistic task with the same stimuli. Strömqvist, Holmqvist & Andersson (2008) recruited two groups of students at Lund University to either watch a series of images constituting a story or to produce a narrative based on the same images presented in an identical manner. The visual attention of the participants was measured using an eye-tracker. The results clearly showed that a narrative task changes the distribution of attention. The nature of the attention differences can, together with the linguistic material elicited, be interpreted in support of a view in which the narrative task unfolds over a number of phases. The visual behavior of the participants in the control task (non-linguistic) was initialized by what seems to be a second-long orientation phase where viewer shifts the gaze approximately 1.5 times per second. This rate drops to around 0.6 shifts per second for the rest of the trial (15 seconds in total). The participants producing a narrative, however, had a longer initial orientation phase (significant for the first two seconds) and then retain a higher rate of attention shifting, approximately 1 shift per second. This shows that the task of producing a narrative forces the participant to direct more attention to areas required by the format of narrative-telling as well as by the grammatical requirements of the particular language. Interestingly, the speakers also produced a more concrete d e s c r i p t i o n, such as physical events, during the first half of the trial. This was followed by a significantly lowered rate of attention-shifting, which the authors call the r e f l e c t i o n phase, which in turn was followed by a r e f o r m u l a t i o n phase where the speaker introduced new and often abstract information such as the mental states of characters.

Although that experiment demonstrates how visual attention can be changed by a linguistic task, it did not investigate effects that are language-specific, which are the interest of research in linguistic relativity. However, Andersson (2005) designed an experiment to investigate more precisely how attention can be guided by language

(cf. Strömqvist & Verhoeven, 2004). In this strand of research, pictorial stimuli are often used to elicit narratives from a large number of languages. The major finding of the previous research is that speakers of different languages do not emphasize the same aspects of a particular event. Whereas speakers of Germanic language typically encode the m a n n e r of a motion (cf. running, jumping, crawling), Romance speakers are relatively more likely to encode only the p a t h of a motion (cf. crossing, descending, exiting). These differences, although not absolute, are striking since they seem to generalize well within the language families. This suggests that the c a u s e of this effect is within the verbalizations of the particular languages and not within the mind of the individual speakers (otherwise, why would the differences cut so clean between languages?). The best explanation so far emphasizes the cognitive ease with which we encode different events using the different languages. Germanic languages have the manner of the motion typically encoded within the main verb and the path (the direction) as an external particle, e.g. 'run to'. Conversely, the Romance languages encode the path of the motion in the main verb instead, with manner as an optional verb gerund (e.g. "crossed the street, running").

Andersson (2005) presented static visual stimuli of events coupled with Swedish utterances containing either a manner verb or a non-manner verb, to simulate the differences between Romance and Germanic languages. For example, a picture of a woman moving about coupled with:

(2a) The woman is **descending** the hill.
(2b) The woman is **sliding down** the hill.

Using eye-tracking methodology and Talmy's (2000) event typology, Andersson found that both speakers and listeners attend more to the involved parts in the picture, e.g. the feet of a mover when manner was a sliding motion. However, although the effect was true on a general level, not all individual verbs showed the same effect. This suggests that perhaps "manner" is not an optimal construct, and there may be better ways to divide up the languages. Still, the manner component more prevalent in Germanic language does influence attention. Since Germanic speakers can easily encode manner information in their utterances, they pay attention to the manner of a motion and select a main verb based on that information. This is similar to speakers of Tzeltal who would, we predict, focus more visual attention on the person whose body position is likely to be encoded in the utterance. We also predict that speakers of Romance languages would be more likely attend to the area suggested by manner information, as a rarer component would have greater relative salience in a Romance language.

4 Visionary outlook

The three above-mentioned strands of research are examples of how eye-tracking methodology can be used as a window on the mind and on human cognitive processes. Our examples are all taken from research areas of particular relevance to the humanities and cognitive science: interpreting pictures and interpreting or producing linguistic

utterances. Our methodology, however, is new or recent to the humanities, it involves the registration of behavior in real time, quantitative analyses and experimental designs aiming at causal explanations (Holmqvist et al. 2011). Taking traditional research areas to a more empirical and experimental level, adding the online dimension, is conducive to partly new research questions. How does the interpretation process unfold in real time (in contrast to the more traditional question: What is the result of the interpretation process)? What are the cognitive consequences of linguistic diversity in terms of channelling of attention or ease of memory retrieval? How are attentional and understanding processes organized in real time when a subject is interacting with a multimedia source?

The multitude of questions and methods in our lab has the added value of attracting experts from different fields of academia. The Humanities Laboratory currently hosts a so-called Linnaeus project, "Cognition, Communication and Learning", where principal investigators from Cognitive Science, Linguistics, Neuropsychology, Logopedics and Neuroscience will spend ten years making a conjoined effort to push the frontiers of science with respect to learning processes, learning disorders, functional models of underlying brain processes, and causal interconnections between low level and high level processes in human interaction and communication. The laboratory furnishes the associated researchers with infrastructure including eye tracking, electrophysiological methods (EEG/ERP), body tracking, and a virtual reality unit.

On a more applied level, we aim to contribute significantly to the process of launching a new generation of methods and tools for the assessment of skills and learning problems based on the online properties of reading, writing, problem-solving, etc. Last but not least, the Humanities Laboratory at Lund University strives to make its facilities more accessible to researchers and advanced students on a national as well as on an international level.

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RÉSUMÉ

Lundský výzkum jazyka a kognice pomocí metody snímání očních pohybů

Jedním z frekventovaných témat, které řeší kognitivní věda a kognitivní lingvistika, je vztah smyslové percepce a řeči. Toto téma je i předmětem zájmu týmu švédských kognitivních vědců a lingvistů z Lundské univerzity. Článek představuje práci v oblasti empirického výzkumu, který se zaměřuje na metodologii výzkumu jazyka a kognice prostřednictvím tzv. snímání očních pohybů (*eye-tracking*). Sérií výzkumů studují autoři (a) procesuální aspekty pozorování obrázků, konceptualizace obrázků a jejich mluveného popisu, (b) existenci a užívání mentálních vizualizací a (c) otázku jazykové relativity, tj. jakým způsobem jazyk ovlivňuje pozornost a myšlení. Autoři se zaměřují na odhalení časových a sémantických souvislostí mezi vizuálními a verbálními daty. Na jedné straně sledují oční pohyby jako reflexi lidského myšlení. Pomocí specifického technického vybavení dokážou určit, který element zaujme pozorovatelovy oči a následně jeho myšlení. Oční pohyb je jedním z nástrojů ke zpřístupnění mysli. Na druhé straně vědci zaznamenávají mluvené segmenty, které jsou jazykovými výrazy ohniska pozornosti. Specifická analýza promluvy umožňuje využít mluvený popis jako další jemné odhalení mysli. Výzkum propojuje metody s různou disciplinární ukotveností a představuje multimodální komparativní metodu přístupu k mentálním procesům. Ukazuje, jak informanti vytvářejí významové jednotky na základě obrázků a jak tyto jednotky zpracovávají zrakem a jazykem. V závěru článku formulují autoři svou vizi o budoucím možném využití metody snímaní očních pohybu pro výzkum jazyka a kognitivních procesů.

SAMMANFATTNING

Lundaforskning om språk och kognition med hjälp av blickbeteendemätning

En svensk forskargrupp från Humanistlaboratoriet vid Lunds Universitet presenterar i den här artikeln tre olika forskningsområden inom språk och kognition, där så kallad eye-tracking metodologi (blickbeteendemätning) har använts som ett fönster till vårt tänkande. I en rad studier (1) undersöker forskarena det dynamiska samspelet mellan hur vi uppfattar, konceptualiserar och beskriver komplexa visuella scener och bilder; (2) använder en kombination av blickbeteendemätning och verbala beskrivningar i syftet att studera mentala visualiseringar; och (3) studerar olika språks kognitiva implikationer samt hur språket i sig påverkar vår uppmärksamhet och vårt tänkande. Avslutningsvis presenterar Lundagruppen sina visioner om hur metodologin i framtiden kan tillämpas i forskningen om språk och kognition.

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