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## FROM AWARENESS TO ACTION: EYE-TRACKING METACOGNITIVE READING STRATEGIES

**Abstract:** Metacognitive reading strategies are central to improving reading behaviour and comprehension, particularly for students reading in a second language (Grabe, 2009; Haukås et al., 2018). However, students' self-reported awareness of these strategies does not always translate into effective use during reading tasks (Veenman & van Cleef, 2019). This study is an attempt to shift from awareness to action by implementing explicit metacognitive reading instruction. A group of first-year international students ( $N = 32$ ) at a Hungarian university participated in a metacognitive reading intervention supported by eye-tracking technology. Participants completed the Metacognitive Awareness of Reading Strategies Inventory–Revised (MARSIR; Mokhtari et al., 2018) and took part in pre- and post-instruction eye-tracking experiments and a reading comprehension exam (Cambridge Reading Test, B1). The instruction comprised 10 × 90-minute sessions, during which metacognitive reading strategies were introduced and practised. The initial eye-tracking experiment revealed a clear gap between students' perceived strategy awareness and their observable reading behaviours. Following instruction, heatmaps and fixation data showed more purposeful, structured reading patterns, reduced fixation durations, and increased attention to task-relevant features. The findings show the potential of explicit metacognitive reading instruction in transforming reading behaviours, highlighting its essential role in second-language academic reading development.

**Keywords:** Metacognition, Academic Reading, Reading Strategies, Eye-tracking, MARSIR

### 1. Introduction

Academic reading is foundational to higher education. It forms the cornerstone through which students engage with the ideas, methods, and debates of their discipline. Through reading, students evaluate and synthesize information, advance their analytical skills, and thus produce knowledge. Ultimately, academic reading is both a tool for learning and a medium for intellectual participation in the academic community (Afdal et al., 2023). Nonetheless, it is often underrated and overlooked in higher education, despite its centrality to academic success. It is frequently

treated as a previously acquired skill, not as a complex academic proficiency that must be continuously learned and explicitly taught. The assumption that reading is a previously acquired skill appears particularly problematic in English-medium instruction (EMI) degrees, which are rapidly going global (Owen et al., 2021).

What makes this issue more relevant is that more and more countries are now offering entire degrees in English as a way to cater to foreign students and to align their educational systems with global standards (Bezborodova & Radjabzade, 2022). Globally, Chinese learners represent the largest and most rapidly growing population enrolled in university-level English-language programmes (Wang et al., 2024). This trend reflects broader patterns of global mobility, the internationalisation of higher education, and the increasing value placed on English-medium instruction. In the Hungarian context, Chinese students have become a prominent presence in the university sector. By 2016, they ranked third among all international students in Hungary and were the largest non-European group, comprising up to 20% of the international student body at the University of Debrecen and 18% at Corvinus University of Budapest (Xueyan, 2020). Their motivations for choosing Hungary include affordable tuition, access to European qualifications, and improved employment prospects, often shaped by parental expectations and aspirations for upward mobility (Li & Primecz, 2023). More recent data show that Chinese students continue to account for approximately 7% of all international students in Hungary, with an estimated 3,500 to 4,000 Chinese nationals enrolled across Hungarian universities in 2022–2023 (Tempus Public Foundation, 2023). Medicine remains a particularly attractive field, as demonstrated by Semmelweis University's international medical cohort, where Chinese students are estimated to number in the hundreds (Semmelweis University, 2024). However, this sustained growth also highlights the academic and cultural challenges these learners face. Li (2020) asserts that students often struggle not only with communication but also with specific academic skills, such as academic reading, partly due to differences in the education system in China.

One promising approach to addressing these reading challenges is metacognitive reading strategy instruction, which has been identified as effective in stimulating reading development. Metacognition refers to the ability to regulate one's own learning through planning, tracking, and evaluating comprehension while reading (Haukås et al., 2018; Klimovich et al., 2023). Extensive research on metacognitive reading has been conducted; however, most studies have utilised self-report questionnaires as their main instrument (Csíkos, 2022; Veenman & van Cleef, 2019). Csíkos (2022) asserts that such instruments do not necessarily reflect learners' reading experience in practice, as they might rely on memory, not real-time behaviours, which might be biased and not reflect their actual reading behaviours (Veenman & van Cleef, 2019). Although research is calling for online methods, very few studies have used a strategy instruction approach to compare students' reading behaviours before and after instruction, and even fewer have used

eye-tracking technology to assess metacognitive reading behaviour, especially with international university students.

Ultimately, this paper aims to answer the following question:

How does explicit metacognitive reading instruction affect the reading behaviour of second language (L2) learners at the university level, as shown by eye-tracking data?

The findings of this study highlight the potential of explicit metacognitive reading instruction in enhancing reading comprehension and promoting a more effective academic reading experience at tertiary education.

## **2. Literature Review**

Academic reading is a high-order cognitive task at the heart of knowledge construction, critical thinking, and tertiary-level academic success (Grabe, 2009; Afdal et al., 2023). However, defining reading comprehension has been a daunting task for researchers. Duke and Cartwright (2021) note that reading comprehension is founded on the interaction of several mutually connected abilities, including word recognition, language comprehension, vocabulary knowledge, fluency, background knowledge, executive control, and metacognitive control. Researchers regularly highlight these factors as among the chief mechanisms defining reading comprehension outcomes (Ghimire & Mokhtari, 2025).

This paper focuses on metacognitive control, as it has been identified as central to reading proficiency, specifically in academic contexts (Haukås et al., 2018). Metacognition is widely defined in theoretical models as comprising two interrelated components: first, knowledge of cognition, and second, regulation of cognition (Flavell, 1979). The former involves an individual's awareness of themselves as learners, their understanding of various task demands, and familiarity with learning strategies (Schraw et al., 2006). The latter, on the other hand, investigates how learners engage in the reading process. In other words, how they approach tasks, monitor their comprehension and strategies, and evaluate the effectiveness of those strategies (Schraw et al., 2006). In investigating awareness, Mokhtari and Reichard (2002) devised an inventory to assess what strategies readers deploy to regulate their reading. MARSIR comprises global reading strategies, problem-solving strategies, and support reading strategies (Mokhtari & Reichard, 2002). MARSIR has been widely used since then, which gave rise to a large number of studies of reading strategy use, beginning with awareness questionnaire studies, instruction studies, or a mixture of both (Mokhtari et al., 2018). Initially, research has shown which different metacognitive reading strategies stronger readers utilise. Alturjman (2024) found that, for example in Hungary, stronger students often made use of problem-solving strategies such as "re-reading to make sure I understand what I'm reading" and "guessing the meaning of unknown words or phrases" rather

than global reading strategies like “checking to see if the content of the text fits my purpose for reading.”

Although MARSİ-R was widely used across many countries and in different contexts, it has received some critiques. Research has raised concern about its reliability given that it is mainly based on respondents’ beliefs (Csikos, 2022; Veenman & van Cleef, 2019). Csikos (2022) found that respondents of such self-report questionnaires might base their answers on memory, rather than actual strategy use. They also tend to overestimate or underestimate their strategy use (Veenman, 2016). What is more is that the list of strategies might remind students of strategies they do not actually use while reading (Veenman & van Cleef, 2019). As a result, research started taking a shift toward utilising instruction-based studies to investigate metacognitive strategy use. Explicit instruction is encouraged as it involves clearly modelling and guiding students through metacognitive reading strategies, through a series of sessions (Kan et al., 2024). While most studies have incorporated standardized reading tests to measure students’ reading improvements (Muhid et al., 2020; Urban et al., 2023), others have used interviews to gain deeper insights into students’ personal perspectives (Al-Khresheh & Al Basheer Ben Ali, 2023; İncirkuş & Beyreli, 2020). Although these studies have yielded valuable results, they primarily focused on students’ outputs rather than on the reading process itself. In response, some researchers have proposed the use of eye-tracking techniques. Eye-tracking, in particular, has emerged as a powerful method for capturing real-time cognitive and metacognitive activity during reading (Godfroid & Hui, 2025). Recent findings indicate that eye-movement indicators such as regressions, fixation durations, and saccade patterns can serve as reliable markers of monitoring and re-evaluation processes (Mézière et al., 2023), offering insights that self-report instruments alone cannot provide.

Although quite a few intervention studies were conducted, most of them have primarily examined domestic learners, leaving a gap in understanding how international students adapt to European academic expectations. This study focuses on Chinese students specializing in medicine as (1) they comprise one of the largest non-European student populations in Hungary, and (2) because medical studies, in particular, demand advanced reading comprehension, involving discipline-specific terminology, dense informational texts, and high levels of retention and reasoning (Alhumsi, 2021). Given these challenges, it remains unclear how metacognitive strategy instruction can support such learners in managing the heavy reading load characteristic of medical programmes.

By combining self-report data, eye-tracking measures, and explicit metacognitive instruction, the present study contributes to the literature by offering a multi-method perspective on how strategy training influences both perceived and observable reading behaviour. It thus addresses a regional gap (international students in Hungary), a disciplinary gap (medical academic reading), and a methodological gap (integrating eye-tracking into intervention research).

Given these insights, the present study aims to explore the overarching question: How does explicit metacognitive reading instruction influence observed reading behaviour among international students in Hungary?

### 3. Method

The intervention involved 32 Chinese learners, all aged 18, enrolled in a preparatory medical studies year (medicine, dentistry, or pharmacy) at a Budapest-based university. The sample included 32 first-year medical students, comprising 18 females and 14 males. Among them, 20 were enrolled in the medicine track, 8 in dentistry, and 4 in pharmacy. Participants were recruited through an in-class announcement, followed by an email invitation distributed to all first-year students in the medical program. Participation was fully voluntary, and students were clearly informed that they could withdraw from the study at any time without any impact on their academic standing.

To determine learners' initial knowledge of their metacognitive reading strategies, a revised version of the Metacognitive Awareness of Reading Strategies Inventory (MARSIR; Mokhtari et al., 2018) was administered. This is a 15-item tool scored on a 5-point Likert scale and measures three key strategy types: Global Reading Strategies (GRS), Problem-Solving Strategies (PSS), and Support Reading Strategies (SRS). Internal consistency for this tool was high, with a Cronbach's alpha of .808. The inventory was administered in a supervised classroom setting to ensure standardised conditions and to minimise response bias. The MARSIR was used solely to establish an initial baseline of students' self-reported metacognitive strategy awareness; its scores were not included in the statistical analyses, as the primary focus of the study was on observable behavioural changes captured through eye-tracking.

Following MARSIR, respondents sat for the B1 Cambridge English Reading Test, a standardised test assessing reading comprehension at the CEFR B1 level. The test includes tasks such as identifying main ideas, understanding specific details, and inferring word meanings from context (Appendix C). Students completed the test under exam-like conditions with a fixed time limit (60 minutes), following official Cambridge administration guidelines to ensure consistency across participants.

An eye-tracking study was then conducted using a Tobii Pro Lab eye-tracker (Appendix B). Eye-tracking has been pinpointed as a powerful and non-intrusive method of garnering information on real-time reading behaviour and cognitive activity. Eye-tracking records a variety of measures, such as fixations, saccades, and regression, which reflect cognitive processing and reading comprehension efficacy (Latimer, 2018; Latimer & Chan, 2022). A fixation is when the eye stops

on a word or phrase for around 100–500 milliseconds which can suggest active processing of an area of interest. A saccade is rapid eye movement between fixations. Regressions are backward saccades, and they show what readers revisit, often due to confusion or reanalysis. Eye-tracking is not only descriptive of what readers do, but also diagnostic and instructional in the context of reading and metacognition. To elaborate, eye-tracking enables researchers to identify metacognitive lapses during reading by revealing where, when, and how long a reader fixates, skips, or regresses on text (Juřík et al., 2025). De-la-Peña (2024) exemplified this by noting that increased regressions and prolonged fixations can indicate comprehension difficulty or active strategy use, for instance, rereading and inferencing. Lu et al. (2022) also asserted that students trained on metacognitive reading displayed more strategic eye movements, namely longer fixations on headings and increased regressions to core content which correlated with higher comprehension scores. Eye-tracking data were recorded at a sampling rate of 60 Hz. A 24-inch monitor was used and a distance of 65 cm for respondents was ensured. A 9-point calibration was used to ensure accurate gaze tracking. A chinrest was also employed to minimize head movements and guarantee calibration accuracy.

In the experiment, four AI-designed texts aimed at assessing a range of reading behaviours and comprehension traits were read by a respondent (Appendix B). To ensure content validity and appropriate difficulty, the four AI-generated texts were reviewed by two experienced English-language instructors who were familiar with CEFR-level reading requirements. These texts served as specific reading assignments: main idea identification, inferring the meaning of words, tracking attention, and information extraction. Three texts were followed by comprehension questions, while the fourth ended with a humorous, nonsensical sentence designed to provoke attention and comprehension tracking. This task aimed to identify variations in reading behaviour between question-relevant and question-irrelevant text regions. In preparation, Areas of Interest (AOIs) were defined to encompass headings, comprehension questions, bolded and plain words, and target text regions.

Following the initial test, learners were given a ten-session intervention in which explicit instruction and practice in using metacognitive reading strategies were given using real reading texts, handouts, and PowerPoint slides. Each session was approximately 90 minutes long. All instructional sessions were delivered by the researcher using a standardised set of lesson materials to ensure procedural consistency. Following the intervention, both the eye-tracking test and the reading comprehension test were administered a second time to detect changes in reading behaviour. Post-tests were administered under the same conditions as the pre-tests to maintain comparability.

As for the data analysis, the first stage of analysis involved examining heatmaps generated by Tobii Pro Lab. Heatmaps were used to provide a visual, qualitative comparison of students' attentional patterns before and after instruction.

These maps illustrated fixation distribution across the texts, with warmer colours indicating greater fixation frequency or longer gaze durations. Following the heatmap analysis, Areas of Interest (AOIs) were used to extract quantitative eye-tracking measures. AOIs included headings, bolded and plain words, multiple-choice questions, and text regions relevant or irrelevant to the comprehension questions. Metrics extracted from these AOIs included fixation count, fixation duration, time to first fixation, first fixation duration, regressions, and fixation measures on more advanced (B2+) vocabulary.

To evaluate statistically such changes, Wilcoxon Signed-Ranks Test in SPSS was used. Being a non-parametric test, it was appropriate because eye-tracking and test data were ordinal, and sample size ( $N = 32$ ) did not meet normal distributional assumptions. It allowed comparison of post- and pre-instructional scores on a range of measures that reflect key metacognitive strategies operationalized in the MARSII-R framework. Ethical clearance to conduct the research was granted by Eötvös Loránd University (ELTE) (Appendix D).

## 4. Results

The paper analysed what insights can be derived from eye-tracking data about students' metacognitive reading strategy behaviour before and after instruction, and how these insights align with students' self-reported responses. Heatmaps were generated from the eye-tracking data. Heatmaps provide insights into participants' reading behaviour while reading. They depict fixation distributions through colour-coded visualizations, in which warmer colours like red and orange show higher fixation frequencies and longer gaze durations, and cooler colours show minimal attention (Niehorster et al., 2025). These heatmaps show which segments of the text were mostly prioritised by the participants, which by implication, indicate their cognitive and metacognitive reading strategies (Měkota, 2024)

Each of the two experiments comprised of four texts in total. AI was used to regenerate similar tests, to avoid biases; the whole conversation with AI can be provided upon request. In comparing student reading behaviour across the two tasks, notable differences in metacognitive reading behaviour emerged. In the initial eye-tracking experiment, students primarily fixated on the introduction and the vocabulary item "irritable," showing evidence of goal-setting and local vocabulary monitoring. However, they largely overlooked the concluding section, missing the opportunity to integrate and reflect on the full meaning of the text, suggesting limited comprehension monitoring. The post-instruction experiment, in contrast, revealed a more balanced and distributed pattern of attention, with students fixating not only on the introduction and key terms like "hydration," but also on the final paragraphs and multiple-choice comprehension questions (See Figures 1 & 2) This indicates improved alignment between reading and task

demands, as students actively engaged with the parts of the text necessary to answer comprehension questions. Overall, the shift from selective to more comprehensive attention patterns suggests growth in strategic reading behaviours, particularly in comprehension monitoring and task-aware scanning.

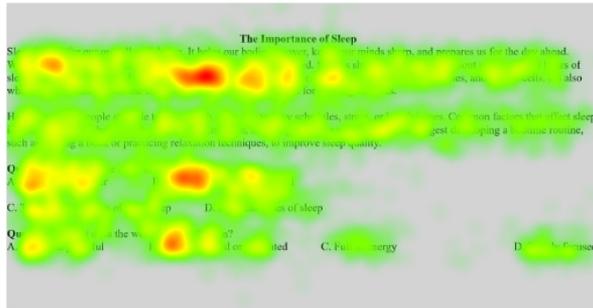


Figure 1: Pre-instruction (Text 1).

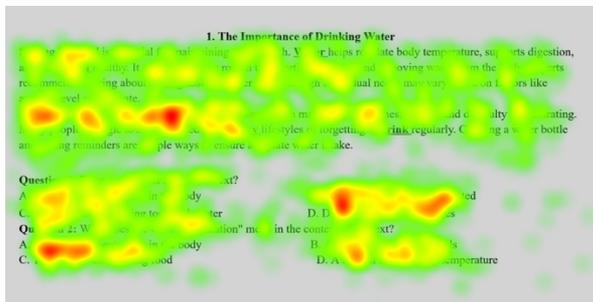


Figure 2: Post-instruction (Text 1).

Another example showed that students' initial reading behaviours showed broad and somewhat scattered attention across the text, with only moderate fixation on specific task-relevant segments. While there was some engagement with the multiple-choice questions and isolated vocabulary terms, the heat pattern suggests a relatively undirected reading style, with weaker signs of strategic focus on key information or question-driven navigation. By contrast, in the post-instruction heatmap, there is clear evidence of improved metacognitive engagement. Students demonstrated stronger fixation on the question prompts and on text sections most relevant to answering those questions, including bolded or underlined terms and answer-aligned segments. Additionally, attention was more sharply directed toward vocabulary-in-context items and structural markers in the text, suggesting enhanced comprehension monitoring, task alignment, and more purposeful scanning (See Figures 3 & 4).

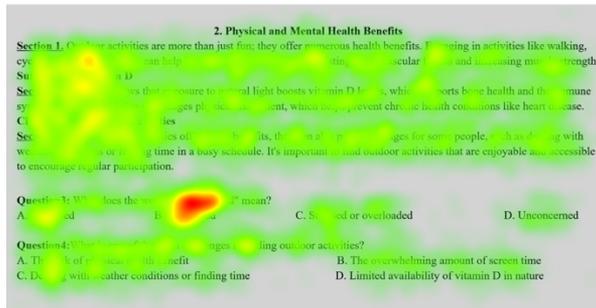


Figure 3: Pre-instruction (Text 2).

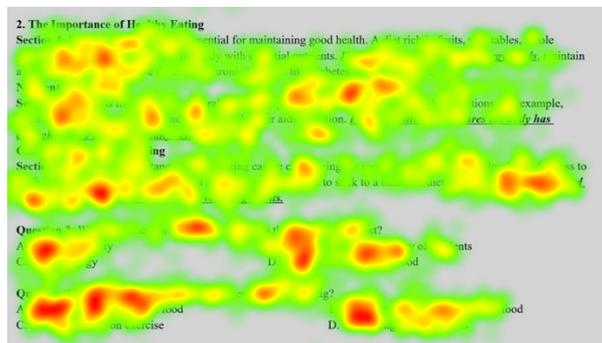


Figure 4: Post-instruction (Text 2).

As a next step, data metrics were derived from Tobii Pro Lab. The eye-tracking data provide strong support that explicit metacognitive reading instruction exerted substantial effects on students' reading behaviour and reading comprehension. To evaluate statistical changes, Wilcoxon Signed-Ranks Tests were conducted in SPSS. Owing to ordinal eye-tracking and test data and the small sample size ( $N = 32$ ), which violated normality assumptions, this non-parametric test was appropriate. It allowed comparison of post- and pre-instruction scores on several measures that correspond to key metacognitive reading strategies.

There were also substantial post-instruction gains in fixation count overall ( $p < .001$ ), which reflects more rigorous processing of text and more frequent use of comprehension-monitoring strategies such as re-reading to ensure understanding and changing reading rate when text becomes difficult. A significant decrease in time until first fixation ( $p = .008$ ) indicates that students were more efficient at identifying relevant information, which matches metacognitive reading strategies of carrying a clear purpose in reading and checking whether the text serves that purpose. Finally, there were significant declines in first fixation time ( $p < .001$ ), which reflects more efficient initial processing of text, perhaps due to previewing or more confident antecedent scanning before engaging deeply with the text. The increase in overall fixation time ( $p = .027$ ), with marginal increases in mean fixation

length ( $p = .063$ ), reflects more sustained cognitive processing and stopping to think when reading: signs of metacognitive regulation. At the lexical level, there were significant increases in fixation number and time spent on words that were B2+ (both  $p = .008$ ), reflecting increased deployment of approaches to checking one's vocabulary, such as guessing unfamiliar words' meanings based on contextual cues.

Interestingly, after training, students allocated much more time to reading question-relevant sections of text ( $p = .008$ ), which indicates more purposeful reading, yet another metacognitive reading strategy. Though fixation on the actual questions themselves didn't significantly differ ( $p = .314$ ), increased attention to relevant text indicates better self-monitoring and correspondence of comprehension, and both of these changes in behaviour were accompanied by a significant enhancement in reading comprehension tests ( $p = .001$ ), also attesting to the success of the intervention.

Overall, results of the Wilcoxon tests confirm that students not only showed heightened metacognitive awareness but also displayed marked changes in reading behaviour that corresponded to key metacognitive reading strategies: re-reading, vocabulary inference, pacing, purposeful reading, and self-monitoring. These findings underscore the significance of explicit metacognitive reading instruction in changing what students read and how they read.

## 5. Discussion and Conclusion

This study was primarily directed by the question of “how explicit metacognitive reading instruction impacts the real-time reading behaviour of international students.” The study primarily made use of pre- and post-instruction eye-tracking experiments. Following instruction, students showed more focused, strategic engagement with texts, characterised by increased attention to task-relevant segments, more purposeful fixations, and clearer signs of active comprehension monitoring. These findings align with previous research that underscores the effectiveness of explicit metacognitive reading instruction in fostering deeper reading comprehension and academic success (Haukås et al., 2018; Ghimire & Mokhtari, 2025). Moreover, this study highlighted the move from self-reported awareness to observable action, which supports the view that strategy knowledge alone is insufficient unless supported by instruction (Veenman & van Cleef, 2019; Csíkos, 2022).

In light of these findings, a more deliberate integration of explicit metacognitive reading instruction is needed in EMI environments. The behavioural changes observed after only ten instructional sessions suggest that learners benefit from explicit guidance on how to navigate academic texts. Teachers and curriculum designers can support this by incorporating brief, targeted activities that model how to preview text structure, examine task demands before reading, annotate key

information, and infer unfamiliar vocabulary from context. These practices closely mirror the strategic behaviours observed in the post-instruction eye-tracking data and can be easily embedded within academic skills or reading-focused courses. Importantly, these observations correspond directly to the significant differences found in fixation count, fixation duration, and first-fixation measures, demonstrating that behavioural improvements accompanied the instructional intervention rather than emerging coincidentally.

This study also raises a broader institutional question: why is academic reading still underemphasised in university curricula, particularly when so much attention is devoted to academic writing? Academic reading is not a passive skill but a complex, higher-order cognitive activity essential for synthesising knowledge, interpreting academic texts, and succeeding in disciplines such as medicine, where reading comprehension has real-world implications. Universities increasingly support academic writing through dedicated courses and writing centres; it is time that academic reading received similar attention—especially in EMI environments, where the gap between language proficiency and academic expectations is often widest. Improvements in reading skills translate directly into better comprehension of lectures, greater confidence in handling lengthy readings, and stronger performance on reading-based assessments. Over time, such strategic behaviours can reduce reliance on rote memorisation or translation and support a smoother progression into discipline-specific courses, ultimately contributing to improved long-term academic performance.

While the sample size in this study was relatively small and limited to one cultural and disciplinary group, the results suggest that structured, explicit metacognitive reading instruction can lead to meaningful change. Future research should explore long-term effects, include more diverse populations, and examine how these strategies interact with other academic skills such as note-taking, summarising, and test-taking. Overall, this study demonstrates that metacognitive reading strategies can be taught, practised, and internalised—and that doing so yields both behavioural and academic benefits. In an era of growing internationalisation in higher education, fostering strong academic readers is not a remedial intervention; it is a necessary foundation for student success. By directly linking observed behavioural changes to the instructional intervention, this study provides empirical evidence that explicit metacognitive strategy training translates into measurable improvements in real-time reading processes and, by implication, academic success in higher education.

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