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Understanding Discoursal Causals in Persian: Evidence From Eye-Tracking

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ABSTRACT

This article investigates how native Persian speakers process and comprehend affirmative and negative discoursal causal assertions. To examine this, an eye-tracking experiment was conducted with 10 male and 20 female Persian-speaking participants. The main experiment involved 32 Persian vignettes, each containing three sentences: an opening sentence, a target sentence (affirmative or negative discoursal causal), and a concluding sentence. The polarity of the target and concluding sentences was varied (affirmative vs. negative) within participants. When participants heard an affirmative discoursal causal assertion (e.g., *Because my skin was dry, I applied moisturizer*), they primarily fixated on the factual phrase ("applying moisturizer"), with a fixation probability of 63%, whereas the conjectural phrase received little attention, attracting only 12% of fixation probability. A similar pattern was observed for negative assertions (e.g., *Because my skin was not dry, I did not apply moisturizer*), where participants focused on the factual phrase ("not applying moisturizer"), attracting only 63% of fixations, largely ignoring the conjecture, with a fixation probability of only %19. Fixation data confirmed that factual phrases consistently received more attention than conjectural ones during early processing stages. In the final analysis, the effect of specificity on fixation patterns was tested. Results showed that specificity did not significantly influence either early attention or increased attention to factual content across polarity conditions. Overall, the findings align with Mental Model Theory, emphasizing the cognitive priority given to factual representations.

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1. Introduction

The inquiry into how causal constructions are mentally represented and evaluated remains a complex and debated issue in fields such as philosophy, law, cognitive science, and psychology. There are theories which have been proposed regarding how causality is processed, one of which is Mental Model Theory. Mental models are personal, internal cognitive representations of external, hypothetical, or imagined realities, which individuals use to interact with the world around them (Johnson-Laird et al., 1998, p. 19; Jones et al., 2011). Craik (1943) argued that people rely on mental models to predict events, reason, and generate explanations. The theory was further developed in 1983 by Johnson-Laird, who proposed that mental models play a central role in human reasoning and understanding. According to the Mental Models Theory, the statement A caused B may represent three possible mental models:

- **a factual possibility**: Both A and B occur.
- **the first counterfactual possibility**: A does not occur, but B does.
- **the second counterfactual possibility**: Neither A nor B occurs. This possibility is considered false or irrelevant. However, even if both A and B occur, the statement *A caused B* is regarded as false if there is no actual causal relationship between them.

Among the three possibilities, the factual and the second counterfactual are generally more cognitively accessible and are thus prioritized in mental representation. In a causal scenario, what actually happens and is directly derived from the sentence can be seen as corresponding to the fact, whereas the counterfactual—what could have happened in the absence of the cause—corresponds to the conjecture (Byrne, 2007; Gerstenberg, 2024; Lucas & Kemp, 2015; McEleney & Byrne, 2006; Oreneset et al., 2021). Byrne (2007) maintains that understanding a causal construction requires only the representation of the fact.

The present study specifically focuses on discoursal causal assertions. Comrie (1992) defines discoursal causal assertions as a type of causative construction in which the notion of causality is conveyed implicitly. In Persian, there are various ways to express discoursal causal assertions (Golfam & Bahrami-Khorshid, 2009).

1. *man gerye kard-am, xāhar-am nārāhat šod-Ø.*
   I cry do.PAST-1SG sister-my upset become.PAST-3SG
   "I cried, my sister got upset."

2. *čon dar ǰašnvāre šerkat na-kard-am ǰāyez(e)-am rā na-gereft-am.*
   because in festival participate NEG-do.PAST-1SG prize-my DO NEG-receive-1SG.
   "Because I didn't participate in the festival, I didn't receive my prize."

3. *be xāter-e moškelāt-e mote?aded dar nahāyat mohāǰerat kard-Ø.*
   because-EZ problems-EZ numerous in end immigration do.PAST-3SG.
   "Due to numerous problems, he eventually emigrated."

4. *vaqti ?u rā did-Ø, ?z šoq labxand mi-zad-Ø.*
   when her/him DO see.PAST-3SG, from joy smiling PROG-hit.PAST-3SG.
   "When s/he saw her/him, s/he was smiling with joy."

The juxtaposition of two sentences—where the first conveys the cause and the second the effect—creates a causative force. Example (3) illustrates the use of a causative or resultative conjunction, which inherently carries a sense of causation and leads to the formation of a causative construction. Example (4) is recognized as a causative structure due to the inclusion of the causative preposition *be xāter-e* ("because of"). In example (5), the presence of the temporal connector *vaqti* ("when") serves as the trigger for conveying a causative meaning.

This connector allows us to express not only the timing of his smile but also its cause, albeit indirectly. Overall, when certain textual or discourse-level features encode a cause-effect relationship, the structure is classified as a discoursal causal, even if no explicit formal marker is present in these types. The variables in our study are those affirmative and negative discoursal causal assertions in Persian whose causative meaning is conveyed through a causative preposition or a causative conjunction.

In example (5), there is an affirmative discoursal causal assertion, as both verbs in the two clauses are affirmative.

5. Because my skin was dry, I applied moisturizer.

According to the Mental Model Theory, in example (5), the fact can be understood as "my skin was dry, and I applied moisturizer," that is, the event that actually occurred in reality. The counterfactual possibility, which is cognitively more accessible than the factual one, represents "my skin was not dry, and I did not apply moisturizer." In example (6), there is a negative discoursal causal assertion, as both verbs in the two clauses are negative.

6. Because my skin was not dry, I didn't apply moisturizer.

Here, the factual possibility is "my skin was not dry, and I didn't apply moisturizer," and the counterfactual is "my skin was dry, and I applied moisturizer."
Considering the above discussion, three questions arise:

1. What is the sequence of eye fixations on the factual and conjectural possibilities among native Persian speakers in the early seconds after hearing an affirmative or negative discoursal causal assertion?
2. To what extent do native Persian speakers fixate on the factual and conjectural possibilities in the early seconds following the auditory presentation of an affirmative or negative discoursal causal assertion?
3. How does the degree of specificity of the factual possibility influence visual attention, and does this differ across affirmative and negative causal assertions?

To clarify this issue, consider the following examples:

7. Because he couldn't get a loan, he didn't buy a Santa Fe.

8. Because he could get a loan, he bought a Santa Fe.

In example (7), which represents a negative discoursal causal, the factual possibility is "he couldn't get a loan and didn't buy the Santa Fe." In this case, the listener cannot easily picture a specific car. Although the Santa Fe was not purchased, one could still imagine that he might have chosen another model—perhaps a Kia Sportage, a Toyota Corolla, or even a Mazda CX-5.

In contrast, in example (8), which is an affirmative discoursal causal, the factual possibility is "he could get a loan and bought a Santa Fe." In this case, the listener can mentally visualize a specific car, namely the Santa Fe, rather than any other option. This higher degree of specificity may lead to earlier and stronger fixations on the factual possibility in affirmative causals compared to their negative counterparts.

To establish the connection between the theoretical framework and the experimental methodology, it should be noted that Mental Model Theory assumes that comprehenders construct internal representations of factual and counterfactual possibilities when processing causal statements. Eye-tracking methodology provides a direct means of testing these assumptions, as patterns of visual attention (e.g., initial fixation sequence, duration, and

proportion of gaze time) can reveal which mental models are prioritized during comprehension. Thus, the research questions of this study—concerning the sequence and extent of fixations on factual versus conjectural possibilities—are grounded in the central claim of the Mental Model Theory that individuals rely on mental simulations to interpret causal relations.

This article is structured into several sections. The first section, which has already been presented, introduces the study and its objectives. The second section presents the literature review of related studies. The third section outlines the research methodology, including data collection tools, materials and a description of the participants. The fourth section describes sampling procedures with details on practice trials and main experiments. The fifth section explains the data analysis procedure. The sixth section presents the results, including t-test results, and the final section discusses the conclusion and compares the findings with other studies.

2. Literature Review

This study differs from experimental research conducted in other languages in terms of its focus on the comprehension of discoursal causal constructions in the Persian-speaking community. However, it shares a methodological similarity with some of these studies through its use of eye-tracking technology. One of the most significant studies reviewed in this context is the research conducted by Orenes et al. (2021). In their study, they examined how native Spanish speakers process and comprehend both affirmative and negative discoursal causal assertions as well as counterfactual conditionals, using the visual-world eye-tracking paradigm. The first part of their study focused on the comprehension of counterfactual conditionals, while the second part investigated the comprehension of causal assertions. In the causal condition, participants first heard an introductory sentence, followed by an auditory presentation of either an affirmative or negative causal assertion. Simultaneously, four words appeared on the screen: one indicating the factual possibility, one indicating the counterfactual possibility, and two distractors. Eye-tracking data were used to measure participants' fixations on the factual and conjectural options. A final comprehension sentence was then presented, and participants responded with "yes" or "no" to judge its truth value. This procedure was repeated in the second experiment, which introduced a two-sentence context as a lead-in. The findings revealed that participants consistently focused first on the factual possibility in both affirmative and negative conditions. Eye fixations were stronger and occurred earlier for affirmative causal sentences, indicating that negation imposes greater cognitive processing demands. The study provides empirical support for explicit negation and offers valuable insights into the mental processing of causality.

Goldvarg and Johnson-Laird (2001), in their study, introduced the mental possibilities that are typically represented when individuals process a causal construction. For example, in a sentence such as *A causes B*, they proposed that the following three possibilities are mentally represented:

- (A and B): both A and B occur
- (A and B): B occurs but A does not
- (A and B): neither A nor B occurs

To test the mental representation of these possibilities, Goldvarg and Johnson-Laird (2001) designed an experiment in which participants were asked to generate a list of possible and impossible scenarios for a given causal sentence. The results showed that participants

generally listed the same mental models predicted by the theory. Moreover, their findings revealed that individuals tend to construct a limited set of mental models when interpreting causal meaning—models that often exclude some logical possibilities. This cognitive limitation was shown to result in systematic reasoning errors in causal inference.

Theoretical studies such as Waldmann and Hagmayer (2013) highlight the role of the Mental Models Theory in causal reasoning. According to this account, individuals often rely on simplified mental representations that capture only the explicitly stated causal link—typically the cause and its effect. Other logically possible alternatives, such as counterfactuals, are either ignored or held peripherally in the mind. As a result, causal assertions tend to be mentally represented as the co-occurrence of two events, with less attention paid to alternative scenarios. In their review, Khemlani et al. (2014) explored how mental models are constructed and employed in interpreting causal relationships. They discuss three main types of reasoning, one of which is hypothetical reasoning, which involves constructing mental models to infer the most plausible explanation for unexpected events. This type of reasoning underlies complex cognitive tasks like medical diagnosis or scientific discovery. For instance, *If the trigger is pulled, the gun will fire. The trigger was pulled, but the gun didn't fire. Why?* Mental models prompt possible explanations such as:

A) Because the gun was unloaded.
B) Because the gun was broken.

The authors also highlight key features of mental models, such as their imagistic nature and reliance on the principle of truth—only representing what is believed to be true. Finally, they cite neuroscientific evidence suggesting that causal mental models are represented in the lateral prefrontal cortex. Johnson-Laird and Khemlani (2017) classify causal assertions based on mental models and the nature of causal relationships they encode. One key category is direct causal sentences, which express a clear and obligatory cause-and-effect link—where the cause inevitably leads to the outcome without intermediaries. For instance, in *Eating protein will cause weight gain* the mental model constructed includes both the cause (eating protein) and the effect (weight gain). The authors note that alternative models, such as scenarios where the cause occurs without the effect, are often omitted from mental representations. This highlights how people tend to form reduced, truth-based models for direct causal assertions.

Non-linguistic experimental studies on causality also suggest that people mentally represent multiple possibilities, including both factual and counterfactual scenarios. Gerstenberg et al. (2017) examined whether causal judgments depend on a cause affecting not only the occurrence of an outcome but also its unfolding. In a visual billiard task, participants judged whether ball A caused or prevented the target ball from entering a pocket, while eye-tracking recorded their gaze. Results showed that counterfactual reasoning strongly influenced judgments: the more certain participants were that the outcome would have differed without the cause, the stronger their causal attribution. This study confirms that counterfactual thinking shapes causal evaluation even in perceptual contexts. Similarly, Krasich et al. (2024) investigated how people judge causes of outcomes, asking whether they rely only on reality or also simulate alternatives. Using eye-tracking in a virtual decision-making game, they found that participants compared both actual and counterfactual scenarios, indicating that causal reasoning involves evaluating what happened against what might have happened.

Beyond the Mental Model Theory, other approaches have also shaped the study of causal reasoning. Counterfactual theories of causation trace their roots to conditional reasoning, expressed as: if A had not occurred, B would not have occurred. The most influential account in this tradition is Lewis's (2000) counterfactual theory of causation, which conceptualizes

causes as *difference-makers*. According to Lewis (1973a), we think of causes as things that make a difference; if the cause had been absent, some effects—or in most cases all of them—would have been absent as well.

Another foundational perspective is offered by Hume (1975), who argued for a regularity-based view of causation: a cause is something that is consistently followed by an effect. Although Hume's approach is not counterfactual, it resonates with counterfactual reasoning, since he also claimed that if the cause were absent, the effect would not occur. However, as empiricist philosophers and psychologists have noted, a key limitation of counterfactual theories is that they may appear indirect, vague, or overly dependent on imagination.

The present study aligns with previous Iranian research in its focus on Persian causal constructions. However, it specifically investigates discoursal causal constructions, which have been examined from a typological perspective in one study (Golfam & Bahrami-Khorshid, 2009). In their study, Golfam and Bahrami-Khorshid (2009) classified Persian causatives within Comrie's (1992) framework, identifying lexical, analytic, and morphological types, and further proposed a new category, termed discoursal causative. While this work was pioneering in highlighting the existence of discoursal causatives, it was essentially descriptive and not experimental.

Thus, no prior research in Persian has experimentally explored the comprehension of discoursal causality from a psycholinguistic perspective. Moreover, this study is the first to employ eye-tracking technology to investigate this phenomenon in the Persian language.

3. Method

In this study, an eye-tracking experiment was designed within the visual-world paradigm, which integrates both auditory and visual information. It provides insights into how linguistic information is integrated with visual context (Huettig et al., 2011). In this experiment, participants were simultaneously presented with visual information on a display screen and auditory information through an audio source. Concurrently, their eye movements were recorded and tracked by an eye-tracking device.

3.1 Data Collection Tools

Participants' eye movements were recorded using a Tobii TX 300 eye tracker. The device recorded the position and movement of both eyes at a sampling rate of 2500 Hz. The experimental task was designed and implemented using Tobii Pro Lab software (version 1.241). All words were displayed in B Nazanin font (size 35) on a 23-inch screen with a resolution of 1920×1080 pixels, positioned 60 cm from the participant. Auditory stimuli were played through the built-in speakers of a Lenovo T440s laptop.

3.2 Experiment Materials

Eight short versions of the 50 general scenarios were created, eight questionnaires were prepared, and 20 Persian speakers rated the acceptability of the sentences to assess their validity. As a result, 36 general scenarios—4 for the practice test and 32 for the main test—with the highest levels of acceptability were selected. For each of these 36 general scenarios, eight short scenario versions were created (see Appendix). These versions varied in three key aspects:

- the type of target word in the second sentence (hypernym[1] or hyponym[2]),
- the polarity of the second sentence (affirmative or negative), and
- the polarity of the third sentence.

As illustrated in Table 1, each short scenario consisted of three sentences, as follow:

1. The first sentence served as an *opening sentence*, establishing the context.
2. The second sentence was the *target sentence*, containing a discoursal causal assertion. This sentence varied across conditions in terms of polarity (affirmative/negative) and type of target word (hypernym vs. hyponym), which were counterbalanced across participants. As a result, four versions of the causal assertion were constructed for each scenario:
   - affirmative–hypernym,
   - negative–hypernym,
   - affirmative–hyponym, and
   - negative–hyponym.
3. The third sentence was the *comprehension sentence*, designed to assess participants' understanding of the target sentence. Its polarity was also manipulated across participants, yielding four types of comprehension sentences. The length of the target sentences was controlled and kept between 5 and 8 words, ensuring uniformity in form and structure across items. All target assertions were also in past tense.

As an example, consider Table 1 including eight scenarios which are organized for clarity and ease of comparison. It should be noted that the manner of their presentation in the experiment was inspired by Orenes et al. (2021).

Table 1. Eight Versions of a Short Scenario for One General Scenario

Opening sentence of the short scenario	The second sentence (discoursal causal assertion)	The third sentence (comprehension sentence)
I have a skincare routine.	Because my skin was dry, I applied moisturizer.	I applied moisturizer.
I have a skincare routine.	Because my skin was dry, I applied moisturizer.	I did not apply moisturizer.
I have a skincare routine.	Because my skin was not dry, I did not apply moisturizer.	I applied moisturizer.
I have a skincare routine.	Because my skin was not dry, I did not apply moisturizer.	I did not apply moisturizer.
I have a skincare routine.	Because my skin was dry, I applied cream.	I applied cream.
I have a skincare routine.	Because my skin was dry, I applied cream.	I did not apply cream.
I have a skincare routine.	Because my skin was not dry, I did not apply cream.	I applied cream.
I have a skincare routine.	Because my skin was not dry, I did not apply cream.	I did not apply cream.

1. A hypernym is a semantic term that denotes a broader category encompassing more specific instances known as hyponyms. For example, reptile is a hypernym of snake because it includes various specific types of reptiles, including snakes, lizards, turtles, and crocodiles.
2. A hyponym is a term used in semantics to refer to a word whose meaning is more specific within a broader category. For example, snake is a hyponym of reptile, as it represents a particular kind of reptile. In this sense, snake is a subordinate term within the larger class of reptiles.

3.3 Participants

A total of 34 participants took part in the study, including 23 women and 11 men. Four participants were excluded because their gaze-point percentage was lower than 80%. As a result, 30 participants (20 women and 10 men) took part in one of the designed test versions. All participants were native speakers of Persian. Although the study aimed to recruit monolingual individuals, sequential bilinguals with Persian as their first language were also included. All participants were required to have normal or corrected-to-normal vision. Those with long eyelashes, droopy eyelids, or heavy eye makeup were excluded due to the risk of artificial reflections interfering with the accuracy of the eye-tracking system.

Participants ranged in age from 18 to 40 years, as the study did not target children or elderly individuals. Those with visual or auditory impairments were excluded, and participants were required to have no prior knowledge of the study's purpose.

All demographic and eligibility criteria—including age, gender, first language, vision, and hearing—were assessed through a pre-experiment questionnaire. Additionally, a handedness questionnaire was administered, though handedness was not considered a variable of interest in this study.

4. Sampling Procedures

Before the experiment began, written informed consent[1] was obtained from all participants. The test was conducted in a dark, sound-attenuated room. Participants were seated at a distance of 60 centimeters from the monitor, and their chins were placed on a chin rest to minimize head movement during the task. The calibration procedure began with a brief explanation of the process to the participant. Calibration was conducted using a nine-point grid displayed on a gray background. By fixating on each point, a correspondence was established between the x/y voltage signals and specific screen positions, allowing the eye-tracking system to accurately record gaze data. The entire calibration process was monitored by the experimenter, and in the event of any error or tracking issue, the procedure was repeated to ensure precise calibration. Calibration quality was assessed in terms of accuracy (the average deviation between the recorded and the actual gaze point) and precision (the stability of the gaze signal during fixation). An error referred to cases where accuracy exceeded 0.5 of visual angle or when tracking loss occurred. In such cases, the calibration procedure was repeated to ensure precise gaze estimation. Recalibration was required for approximately 15% of participants, typically no more than once per session.

4.1 Familiarization Phase: Practice Trials

To familiarize participants with the task, a practice session was conducted following the calibration process. In this phase, four practice scenarios were presented, none of which were reused in the main experiment. The instructions provided during the practice session were identical to those in the main task and were also explained orally by the experimenter to ensure clarity. After completing the practice trials, participants proceeded to the main experiment by pressing the space bar.

4.2 Main Experiment

Following the practice phase, the main task proceeded as follows:

1. This study has been approved by the Research Ethics Committee under the code: IR.MODARES.REC.1402.069

- A gray screen with a central fixation cross (+) was presented to help the participant fixate on the center of the display. Simultaneously, the introductory sentence (sentence 1) was played auditorily. The duration of this screen varied depending on the length of the spoken sentence.
- Four target phrases were then displayed on the screen—two vertically (top and bottom) and two horizontally (left and right). The phrases on the screen were in the infinitive form: one representing the factual possibility, another representing the conjectural possibility, and the remaining two serving as distractors. For example, in response to the sentence *Because my skin was dry, I applied moisturizer*, the phrase "applying moisturizer" corresponded to the factual possibility, "not applying moisturizer" to the conjecture, and "applying cream" and "not applying cream" served as distractors.
- The positions were randomized across scenarios. Areas of Interest (AOIs) were defined around these phrases for eye-tracking data collection. This display lasted for approximately 3000 milliseconds.
- While the four words were still displayed on the screen, the discoursal causal sentence (sentence 2)—either affirmative or negative—was played. The audio duration varied depending on sentence length.
- After the sentence finished playing, the four words remained visible for an additional 4000 milliseconds.
- Next, the comprehension sentence (sentence 3) appeared along with two response options: "True" (bottom right) and "False" (bottom left).
- Participants were instructed to judge the truth value of the comprehension sentence. They pressed the J key for "True" and the F key for "False."
- Participants had up to 10 seconds to respond. Once a key was pressed, the next trial began.
- No feedback was provided regarding whether the participants' response was correct or incorrect.
- A total of 36 scenarios were presented in the main experiment, with the order and content randomized across participants. An overview of the trial sequence is illustrated in Figure 1.

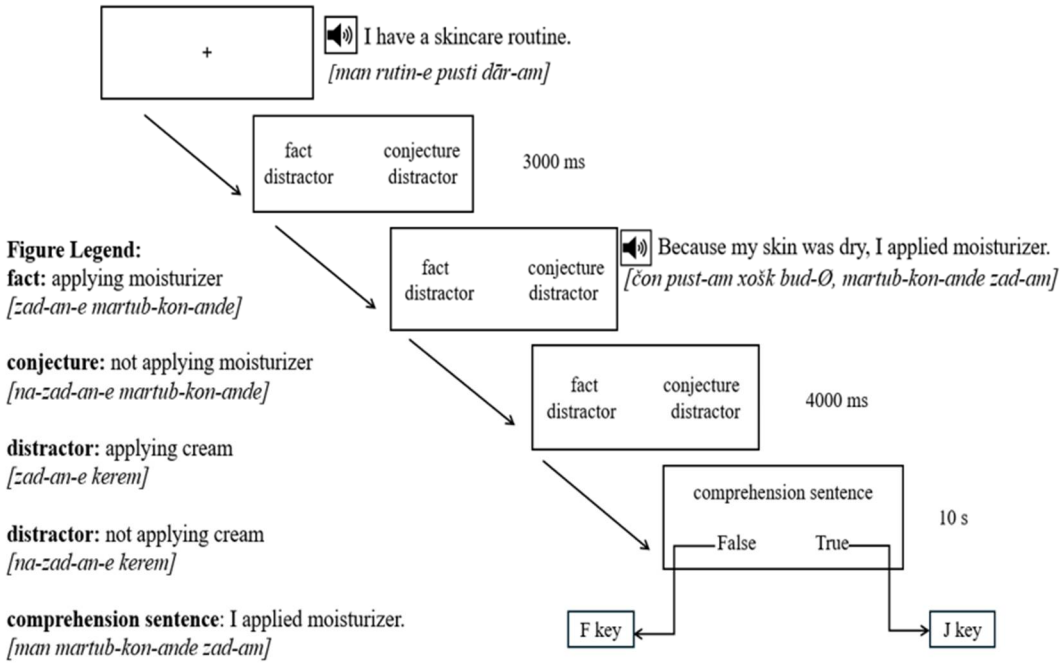

Figure 1. The Procedure of the Main Experiment

5. Data Analysis Procedure

All data analyses were conducted using R statistical software (version 4.3.1). Eye fixation analysis was conducted from the onset of the verb in the second clause (i.e., the result clause) of the target sentence (discoursal causal assertion) and continued for 1500 milliseconds after that point. For example, in the sentence *Because my skin was dry, I applied moisturizer*, the analysis window began when the verb "applied" was first heard, and extended 1500 ms forward.

The time window was segmented into 60-millisecond bins. Within each bin, the number of fixations on each of the four Areas of Interest (AOIs) was calculated. These included one phrase corresponding to the factual possibility, one phrase corresponding to the counterfactual (conjecture), and two distractor phrases (e.g., "applying moisturizer," "not applying moisturizer," "applying cream," "not applying cream"). The fixation counts on each AOI were then divided by the total number of fixations in that interval to obtain the probability of fixation for each AOI.

To ensure reliability, saccades (rapid eye movements) were excluded from the analysis. Based on prior findings (Altmann & Kamide, 2004), the first 100–180 milliseconds after auditory input may reflect oculomotor planning rather than actual processing. Therefore, the average fixation probability during the first two bins (0–60 ms and 60–120 ms) was computed and treated as the baseline. This baseline was then used to compare fixation probabilities across the remainder of the time window up to 1500 ms.

Employing this baseline enabled us to control for early anticipatory biases in gaze behavior, which might otherwise be influenced by sentence structure or lexical properties. Moreover, this approach smoothed out short-term fluctuations and provided a stable reference point for statistical comparisons.

6. Results

In the following section, we present the eye-tracking data analysis for both affirmative and negative discoursal causal sentences.

As illustrated in Figure 2, the fixation patterns of participants in response to affirmative discoursal causal assertions (e.g., *Because my skin was dry, I applied moisturizer*) reveal an early and consistent focus on the factual possibility. At the onset of the verb in the second clause ("applied"), participants initially fixated on the factual phrase ("applying moisturizer") with a probability of approximately 0.05. This initial attention may partly reflect a general tendency to look at items presented on the screen.

From Time Point 2 (i.e., 120 milliseconds after verb onset), fixations on the factual possibility increased progressively and remained high throughout the analysis window. Although there were brief dips at Time Points 7 and 9 (350 ms and 450 ms), the fixation rate recovered quickly and peaked during Time Points 8 to 12 (480–720 milliseconds), indicating a sustained and dominant focus on the factual phrase.

In contrast, the conjectural possibility ("not applying moisturizer") received near-zero fixation probability at the beginning of the verb onset, with only minor attention thereafter—likely due to initial curiosity about the visual items rather than actual processing. Fixations on the conjecture decreased steadily and remained minimal.

Similarly, the two distractor phrases ("applying cream" and "not applying cream") received little attention from the beginning and showed a declining trend over time.

Taken together, the data suggest that when processing an affirmative discoursal causal assertion, native Persian speakers predominantly focus on the factual possibility, with minimal activation of the conjectural alternative.

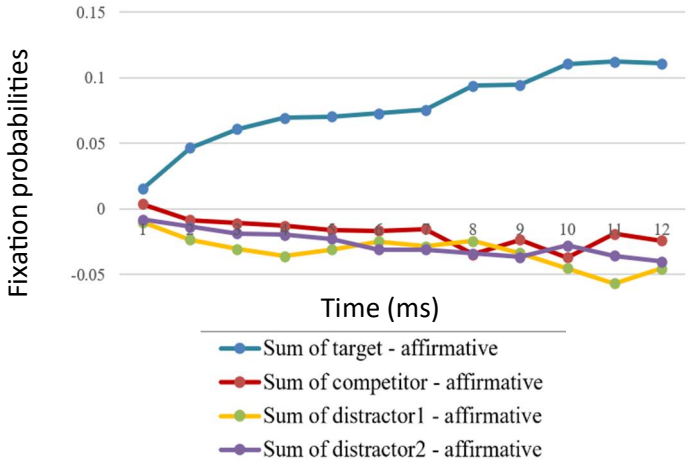

Figure 2. Average Fixations–Affirmative Discoursal Causal Assertions

Figure 3 illustrates the difference in participants' attention and gaze between the fact, conjecture, distractor 1, and distractor 2 in affirmative discoursal causals, along with the probabilities of fixation on these four areas.

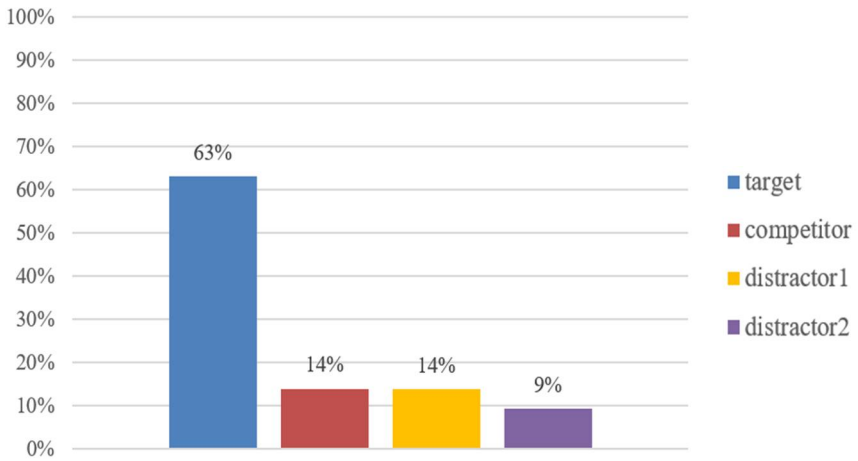

Figure 3. Average Percentage of Fixation Probabilities Across the Four Phrases in Affirmative Discoursal Causals

As depicted in Figure 4, in response to a negative discoursal causal sentence such as *Because my skin was not dry, I did not apply moisturizer*, participants initially focused on the phrase corresponding to the factual possibility ("not applying moisturizer"). The initial fixation probability on the factual phrase was approximately 0.03, and this value steadily increased, reaching its peak by the end of the time window. Although a slight drop was observed at Time Point 8 (480 milliseconds), the fixation trend quickly recovered and continued to rise.

In contrast, at the onset of the verb in the second clause ("did not apply"), fixation probabilities on the other three phrases—including the conjecture ("applying moisturizer") and the two distractors ("applying cream" and "not applying cream")—were near zero and continued to decline over time. This pattern clearly indicates that participants paid minimal attention to these alternative possibilities.

Overall, these findings suggest that native Persian speakers, when presented with negative discoursal causal assertions, predominantly focus on the factual possibility encoded in the sentence and do not actively engage with the counterfactual or irrelevant alternatives.

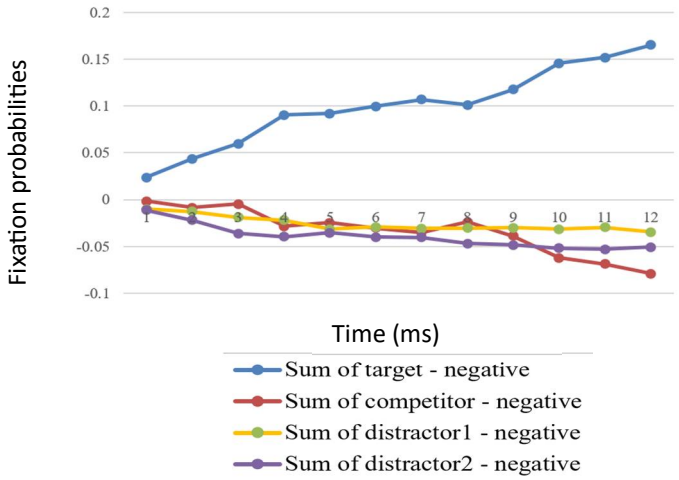

Figure 4. Average Fixations–Negative Discoursal Causal Assertions

For a comparison of the fixation probabilities of the negative discoursal causal fact, conjecture, distractor 1, and distractor 2, see Figure 5.

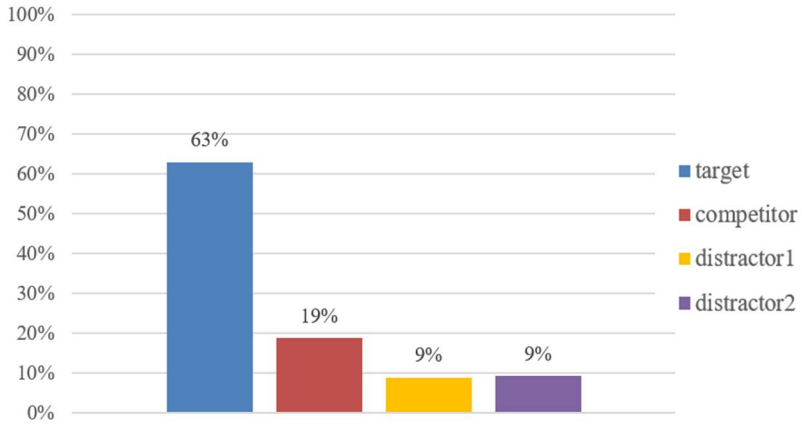

Figure 5. Average Percentage of Fixation Probabilities Across the Four Phrases in Negative Discoursal Causals

6.1 t-test Result

In this study, 28 paired-sample t-tests were conducted to statistically analyze fixation probabilities. These analyses compared fixation probabilities across different polarity conditions (affirmative vs. negative discoursal causals) and areas of interest (AOIs)—namely factual phrases, conjectural phrases, and distractor items.

Eye-tracking data collected from participants were analyzed to examine fixations on each AOI. Specifically, the mean fixation probabilities were calculated for affirmative factual phrases, negative factual phrases, affirmative conjectures, negative conjectures, distractor 1 and distractor 2 (under both polarity conditions).

To assess the significance of differences in mean fixation probabilities between various conditions (e.g., affirmative fact vs. negative conjecture), the standard error of the mean difference was computed. Then, t-values—representing the ratio of the mean difference to the standard error—were calculated.

To evaluate statistical significance, the p-value for each comparison was obtained. If the p-value was below .05, the result was considered statistically significant. To control for Type I error (false positives) due to multiple comparisons, the Bonferroni correction was applied to adjust the significance threshold.

The results of some of the t-tests, including comparisons between fixations on factual, conjectural, and distractor phrases in both affirmative and negative discoursal causal sentences, are summarized in Table 2.

Table 2. Paired-Sample t-test Results

Comparisons	Average Difference	Standard Error	Degrees of Freedom	t-value	p-value
Fact vs. Conjecture in Affirmative Causal assertions	–0.492165	0.0065	60244	–75.671	< .0001
Fact vs. Conjecture in Negative Causal assertions	–0.441840	0.00567	60244	–77.877	< .0001
Fact in Affirmative vs. Fact in Negative Conditions	0.001154	0.00610	60244	0.189	1.0000

The paired-sample t-tests revealed that participants consistently fixated significantly more on factual phrases than on conjectural phrases in both affirmative and negative discoursal causal conditions. In the affirmative condition, the mean difference was –0.492165 (SE = 0.0065), $t(60244) = –75.671$, $p < .0001$. In the negative condition, the mean difference was –0.441840 (SE = 0.00567), $t(60244) = –77.877$, $p < .0001$. These results indicate a robust and statistically significant preference for factual information across both polarity conditions.

No significant difference was observed between the fixation probabilities on factual phrases in affirmative versus negative conditions (mean difference = 0.001154, $t = 0.189$, $p = 1$), suggesting similar cognitive prioritization of factual content regardless of polarity.

In contrast, fixations on distractor phrases (e.g., "applying cream," "not applying cream") remained low and relatively uniform across conditions, with negligible differences (e.g., 0.048740 and 0.045291), confirming that irrelevant information was largely ignored.

These findings support the view that native Persian speakers primarily attend to factual possibilities when processing both affirmative and negative discoursal causal statements.

7. Conclusion

In the first phase, the sequence of mental representations of the factual and conjectural possibilities was examined during the comprehension of affirmative and negative discoursal causal assertions.

The findings indicate that Persian speakers primarily focus on the factual possibility, and the conjectural possibility—whether in affirmative or negative assertions—was not activated and remained close to zero.

As previously discussed, various theories exist in the domain of causal processing. One such theory is the Mental Models Theory, which posits that when people process a causal assertion, they may represent multiple possibilities, including the factual possibility (what

actually happened) and the conjectural possibility (what could have happened in the absence of the cause) (Goldvarg & Johnson-Laird, 2001, p. 570). According to the Mental Models Theory, people typically rely on reduced representations that include only the main meaning of the assertion. They tend to ignore or marginalize other possibilities in their minds. The theory predicts that individuals often interpret causal relationships merely as the co-occurrence of two events, and tend to overlook other plausible scenarios that are still logically compatible with the causal assertion (Waldmann & Hagmayer, 2013, p. 8). Byrne (2005, 2007) notes that counterfactual thinking requires more cognitive effort. Therefore, when encountering a causal assertion, individuals, in line with the principle of cognitive economy, are more likely to focus on the option that entails the least processing cost rather than maintaining several possibilities in working memory. This is because the greater the number of mental representations, the heavier the load on working memory, and the more difficult reasoning becomes (Bauer & Johnson-Laird, 1993; García-Madruga et al., 2001).

In addition, another principle of the Mental Models Theory is the principle of truth, meaning that individuals construct mental representations that are true and factual, not false (Goldvarg & Johnson-Laird, 2001, p. 567). For example, in a sentence like *Because my skin was dry, I applied moisturizer*, listeners are likely to mentally represent only the true possibility, "my skin was dry and I applied moisturizer," while the counterfactual possibility, "my skin wasn't dry and I didn't apply moisturizer," is treated as false and thus not retained in the mental model.

According to the findings of this study, Persian speakers, when processing either affirmative or negative discoursal causal assertions, focused solely on the factual possibility, while the conjectural possibility was not activated. Therefore, it is evident that their eye fixations were directed only toward the factual possibility, and as time progressed, the amount of fixation on the factual element increased significantly. This pattern is consistent with the eye-tracking study conducted in Spanish by Orenes et al. (2021), which showed that individuals, when encountering affirmative or negative causal assertions, focused only on the factual possibility, and their eye fixation on this element steadily increased over time. The findings of the present study are thus aligned with the results observed in Spanish.

As discussed earlier, individuals tend to mentally represent causal assertions as co-occurring events. Other possibilities—such as the counterfactual, equivalent to the conjectural possibility—are often forgotten due to limitations of working memory. Additionally, it should be noted that people generally have a cognitive bias toward reality-based information, and real meanings are cognitively preferred over counterfactual ones (De Vega & Urrutia, 2012).

According to the findings of Orenes et al. (2021) in Spanish, both the amount and speed of eye fixation on the factual possibility were greater in affirmative causal assertions than in negative ones. This indicates higher specificity in affirmative causal sentences. However, the current study found no such difference in Persian.

One possible reason for the lack of difference in early or greater attention to the factual possibility in affirmative versus negative assertions could lie in how the four phrases (fact, conjecture, and two distractors) were presented—as infinitive verb forms. For example, when participants see "applying moisturizer" as *zadan-e martub-kon-ande* or "not applying moisturizer" as *na-zadan-e martub-kon-ande*, the verb forms *zadan* and *nazadan* are processed as single word tokens. Therefore, both affirmative and negative infinitives are processed in a very similar way. Hence, in Persian, negative infinitives pose little additional processing demand compared to affirmative ones, because both are treated as similar units.

Additionally, the use of infinitives in Persian led to a close match between the verb heard in the second clause of the assertion and the visual options on screen, regardless of polarity.

This likely contributed to the equal attention received by the factual possibility in both affirmative and negative assertions.

Therefore, we conclude that the effect of specificity was neutralized in this experiment.

Ethical Considerations

The study was conducted in compliance with ethical guidelines (Ethics Code: IR.MODARES.REC.1402.068). All participants gave their informed consent prior to taking part in the study. They were informed about the nature of the research, their right to withdraw at any time without penalty, and the confidentiality of their data.

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Conflict of Interest

The authors declare no conflicts of interest related to this research.

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Appendix

First sentence	Second sentence (target)	Third sentence (comprehension)
Ali is the owner of a livestock farm.	Because he had a good business sense, he sold milk there.	Ali sold milk.
Amir is a graduate in architecture.	Because his portfolio was impressive, he was offered to design a tower.	Amir wasn't offered to design a tower.
Mina used to walk to work every day.	Because she had an important work meeting yesterday, she came by car.	Mina came by vehicle.
Morvarid went to paintball.	Because her clothes had gotten dirty, she bought detergent.	Morvarid didn't buy detergent.
I went to Ferdowsi Square.	Because the exchange office wasn't crowded, I got some dollars.	I got dollars.
Mani went to a café.	Because he was feeling cold, he ordered tea.	Mani didn't order tea.
Mitra went to the gym.	Because she had free time after work, she signed up for a karate class.	Mitra signed up for a karate class.
Hamid went to the East Mobile Market.	Because his salary was high, he bought an iPhone.	Hamid didn't buy a mobile phone.
Pedram bought a gift for his friend's birthday.	Because his friend liked reading, he gave him a novel as a gift.	Pedram gave a novel as a gift.
We went out with our friends.	Because we were craving fast food, we ordered pepperoni.	We ordered pepperoni.
Narges had the day off today.	Because she had time, she made Ghormeh sabzi.	Narges made stew.
Nader was on his way home.	Because the produce market was nearby, he bought oranges.	Nader bought oranges.
Sina went to the car exhibition.	Because he got a loan, he bought a Pride.	Sina didn't buy a Santa Fe.
Farzaneh went to the shopping mall.	Because her engagement was coming up, she bought a ring.	Farzaneh bought a ring.
Ahmad wanted to go for a walk.	Because it was raining, he wore a coat.	Ahmad wore warm clothes.
Saeed had a few trees in the garden.	Because it was winter, he pruned the plane trees.	Saeed pruned the plane tree.
Yasaman was looking at the flowers.	Because she was wearing a T-shirt, a bee stung him.	A bee stung Yasaman.
Roya checked the Digikala website for Black Friday.	Because the products were on sale, she bought sneakers.	Roya bought sneakers.
Samira went to the Book City.	Because the prices were reasonable, she bought pencils.	Samira bought pencils.

Nima came to school.	Because he had lost the previous day's game, he brought chips for his friends.	Nima brought chips.
Raha was busy preparing for the party.	Because her hands were greasy, the plate slipped from his hands.	The plate slipped from Raha's hands.
Shima went to the kitchen.	Because she was going to make Ash, she soaked the beans.	Shima soaked beans.
Saman cooked food for the party.	Because his food looked dull, he added turmeric.	Saman added spices to the food.
Yesterday, Ali went to the bakery.	Because he woke up early, he bought Sangak bread.	Ali bought Sangak bread.
Yesterday, I went to a café-pastry shop with my friends.	Because my coffee was bitter, I ordered apple pie.	I ordered apple pie.
Narges went out in the polluted air.	Because she had a headache, she took a painkiller.	Narges didn't take a pill.
Masoud went to the lab for a checkup last month.	Because he had done his tests on time, the doctor diagnosed his diabetes.	The doctor diagnosed diabetes.
I have a skincare routine.	Because my skin had become dry, I applied moisturizer.	I applied cream.
Naser is always alone at home.	Because he had a private yard, he got a canary.	Naser got a canary.
Saman went to his coworker's house.	Because it was his first time visiting his coworker's house, he bought a basket of roses.	Saman didn't buy a flower basket.
Zahra used to go to the gym.	Because her coach told her to, she removed rice from his diet.	Zahra removed carbohydrates from her diet.
Hamed went to the doctor for a checkup.	Because he had a lung condition, he quit smoking.	Hamed quit smoking.