

Supplement Documents

Article title: Beyond Text Generation: Assessing Large Language Models' Ability to Reason Logically and Follow Strict Rules

Journal name: AI

Author names and affiliation: Zhiyong Han¹, Fortunato Battaglia^{1,2}, Kush Mansuria¹, Yoav Heyman¹, and Stanley R. Terlecky¹. ¹Department of Medical Sciences, Hackensack Meridian School of Medicine, Nutley, NJ, USA; ²Department of Neurology, Hackensack Meridian School of Medicine, Nutley, NJ, USA.

E-mail address of the corresponding author: zhiyong.han@hmsom.edu

Document 1: Examples of how LLMs describe word ladder puzzles and rules governing how to solve the puzzles.

To assess the knowledge of LLMs about word ladder puzzles, we prompted them with this: What is a word ladder puzzle and what are the rules for creating and solving a word ladder puzzle? Below are typical responses from each of the five LLMs.

ChatGPT4o: A word ladder puzzle is a word game invented by Lewis Carroll in 1878. The objective of the game is to transform one word into another by changing one letter at a time, with each intermediate step being a valid word.

Rules for creating word ladder puzzles:

1. Start and End Words: Select two words of the same length. The first word is the starting point, and the second word is the target.
2. Word Length Consistency: Both the start and end words, as well as all intermediate words, must have the same number of letters.
3. Single Letter Change: Each step in the word ladder involves changing exactly one letter from the previous word to form a new valid word.
4. Valid Words: All intermediate words must be valid, recognizable words in the dictionary.
5. No Repeats: Each word in the ladder must be unique; no word is repeated.
6. Letter Positions: In each step, the position of letters that are not being changed must remain the same. Only one letter changes in each step.

Tips for Creating Word Ladder Puzzles:

- Dictionary: Ensure you have access to a good dictionary to verify the validity of words.
- Planning: Sometimes it's helpful to plan the steps in advance, especially for longer word ladders.

Claude: A word ladder puzzle is a type of word game where the goal is to transform one word into another word by changing one letter at a time, creating a new valid word with each step. The rules for creating word ladder puzzles are as follows:

1. Start and end words: Choose two words of the same length to serve as the start and end words of the ladder.
2. Valid words: Each intermediate step in the ladder must form a valid word that can be found in a standard dictionary.
3. One letter change: Each step in the ladder must involve changing only one letter from the previous word. Rearranging letters or modifying more than one letter at a time is not permitted.
4. Word length: All words in the ladder, including the start and end words, must have the same number of letters.
5. Shortest path: The goal is to find the shortest possible sequence of words that transforms the start word into the end word, following the one-letter-change rule.

Gemini: A word ladder puzzle is a brain teaser that tests your vocabulary and logic skills. Here's how it works:

Imagine a ladder where each rung is a word. You start at the top word and climb down rung by rung, changing one letter at each step, until you reach the bottom word. The challenge is to find a valid word at each step that connects the two words.

Rules:

1. You are given two words, a starting word and an ending word. Both words should be the same length. (think: CAT and DOG)
2. At each step (rung on the ladder), you can only change one letter of the previous word.
3. The new word created by changing a letter must be a real word found in a dictionary (proper nouns are usually not allowed).
4. There can be multiple solutions to a word ladder puzzle, so the challenge is to find one or even all the possible paths.

Meta AI: A word ladder puzzle, also known as a word chain or word association, is a word game that involves changing one word into another word by changing one letter at a time, with each resulting word being a valid word.

Rules for Creating Word Ladder Puzzles

1. Start and End Words: Choose two words with the same length, typically 5-7 letters. These words will be the starting and ending points of the ladder.
2. One-Step Changes: Change one letter at a time to form a new word. Each new word must be a valid, recognizable word.
3. No Repeats: No word can be repeated in the ladder.
4. Valid Words Only: All words in the ladder must be found in a standard dictionary.
5. No Proper Nouns: Avoid using proper nouns, abbreviations, or words that require a hyphen or an apostrophe.
6. Same Word Length: All words in the ladder must have the same number of letters as the start and end words.

Mistral: A word ladder puzzle is a type of word game where the goal is to transform one word into another word by changing one letter at a time, while creating valid words at each step. The words are required to be of the same length. The puzzle is often presented in a ladder-like format, with the starting word at the bottom and the target word at the top.

Here are the basic rules for creating word ladder puzzles:

1. Choose two words of the same length to serve as the starting and ending words. These words should be different enough to require several steps to transform one into the other, but not so different that it's impossible to find a solution.
2. Ensure that each intermediate step forms a valid word. At each step, only one letter can be changed, and the resulting word must be a real, valid word that can be found in a standard dictionary.
3. The ladder should be solvable without requiring players to guess or use obscure words. Ideally, the words used should be common and familiar to the intended audience.
4. Optionally, you can set a specific number of steps for the ladder. This can be done by limiting the number of intermediate words or by specifying the number of changes required to complete the puzzle.

Document 2: Puzzles with solutions Created by LLMs. Repeated words are in green. The words in blue are those with altered length. More-than-one letter changes are shown in purple. Red words are invalid.

By ChatGPT4o

Puzzles with solutions

1. Cat → Cot → Dot → Dog
2. Head → Heal → Teal → Tell → Tall → Tail
3. Cold → Cord → Card → Ward → Warm
4. Love → Lave → Late → Hate

Unsolvable puzzles (explanation)

1. Tall to Short (start and target words are different lengths)
2. Dark to Light (start and target words are different lengths)
3. King to Queen (start and target words are different lengths)
4. Fire to Ash (start and target words are different lengths)
5. Milk to Cow (start and target words are different lengths)
6. Cake to Baking (start and target words are different lengths)
7. Book to Shelf (start and target words are different lengths)
8. Life to Death (start and target words are different lengths)
9. Moon to Sun (start and target words are different lengths)
10. Hill to Mountain (start and target words are different lengths)
11. Apple to Orange (start and target words are different lengths)

Puzzle solutions with rule violations

1. Fish → Fist → **Fist** → Mist → Mint → Pint → **Pond**
2. Sink → Sink → Sing → Sine → **Sime** → Swim
3. Lion → Lien → **Line** → **Lire** → Lira → **Bira** → Bear
4. Mice → Mace → Race → **Rats**
5. Wolf → **Welf** → Self → Sell → Cell → Call → Calm → **Lamb**
6. Hand → Hard → Hord → Hold → Holy → **Hoot** → Foot

7. Star → Stir → Stor → Ston → Moon
8. Note → Note → Nota → Nita → Tite → Tite → Tone
9. Tree → Trea → Trea → Trea → Tood → Wood
10. Fast → Last → Lash → Lish → Lose → Lowe → Slow
11. Blue → Blur → Burr → Burk → Bunk → Punk → Pink
12. Fair → Fain → Fain → Fain → Gain → Goin → Good
13. Pear → Peau → Plau → Plau → Plam → Plum
14. Cook → Coop → Moop → Momp → Moma → Meal
15. Wind → Wand → Bond → Bond → Bond → Bond → Blow

By Claude

Puzzles with solutions

1. Pale → Bale → Bald → Bold → Cold
2. Seed → Weed → Weld → Wild → Wind → Wing → Sing
3. Melt → Belt → Bolt → Boot → Loot → Loft

Unsolvable puzzles (explanation)

- | | | | |
|-----------|----|--------|--|
| 1. Arch | to | Beach | (start and target words are different lengths) |
| 2. Duty | to | Pulps | (start and target words are different lengths) |
| 3. Fable | to | Gambol | (start and target words are different lengths) |
| 4. Broom | to | Bail | (start and target words are different lengths) |
| 5. Binge | to | Ting | (start and target words are different lengths) |
| 6. Ample | to | Amiss | (start and target words are different lengths) |
| 7. Weave | to | Maze | (start and target words are different lengths) |
| 8. Broil | to | Scroll | (start and target words are different lengths) |
| 9. Crank | to | Gave | (start and target words are different lengths) |
| 10. Smite | to | Mure | (start and target words are different lengths) |
| 11. Talus | to | Ballus | (start and target words are different lengths) |
| 12. Quail | to | Duli | (start and target words are different lengths) |
| 13. Lapse | to | Brise | (A solution could not be found) |
| 14. Glaze | to | Slear | ("Slear" is an invalid word) |

Puzzle solutions with rule violations

1. Spire → Spire → Shire → Shite → Suite → Quite → Quite → Quire
2. Thyme → Chyme → Chime → Shine → Shone → Shone → Phone → Phony
3. Chant → Chart → Chary → Chary → Charm → Charm → Charr → Chair
4. Easel → Ease → Ease → Erase → Erate → Irate → Irate → Inert
5. Plume → Plume → Prune → Prine → Prime → Grime → Grime → Gripe
6. Woven → Woven → Coven → Cover → Lover → Laver → Lacer → Racer
7. Flare → Flair → Flair → Flair → Fail → Frail → Frail → Trail
8. Gauge → Gauge → Gaupe → Gaupe → Grape → Gripe → Gripe → Grime
9. Pinch → Punch → Punch → Bunch → Burch → Burch → Burch → Birch
10. Cower → Power → Paver → Paver → Paver → Raver → Raver → Raver → River
11. Limbo → Limbo → Limbo → Nimbo → Nimbo → Gumbo → Gumbo → Gumbo → Gumbo → Bumbo
12. Munch → Bunch → Bnnch → Bnnch → Bncch → Bncch → Bnoch → Bnock → Knock
13. Trice → Trace → Trace → Truce → Truce → Truce → Truce → Truck

By Gemini

Unsolvable puzzles (explanation)

1. Fun to Warm (start and target words are different lengths)
2. Book to Fun (start and target words are different lengths)
3. Fun to Mind (start and target words are different lengths)

Puzzle solutions with rule violations

1. Face → Fade → Bade → Bake → Book
2. Deep → Keep → Keep → Reich → Rich
3. Safe → Fade → Flan → Plan
4. Game → Came → Came → Came → Fade → Find
5. Dust → Dove → Lose → Lose → Love
6. Idea → Idea → Edea → Eade → Cake
7. Rain → Rain → Ripe → Hipe → Hear
8. Hope → Hose → Mose → Mine → Mind
9. Burn → Burn → Turn → Tune → Wave
10. Fish → Wish → Wish → Whist → Whisp → Glad
11. Cold → Cod → Cod → Kid → King
12. Play → Pay → Pay → Say → Saye → Cake
13. Free → Flee → Flew → Flue → Flume → Deep
14. Warm → Warn → Warn → Worn → Worn → Hear
15. Hear → Hear → Heat → Feat → Fast
16. Gift → Graft → Draft → Drift → Shift → Safe
17. Goal → Coal → Coat → Rust → Rich
18. Love → Lose → Lose → Close → Close → Climb → Clime → Game
19. Cake → Cave → Dave → Dive → Dust
20. Mind → Find → Find → Fund → Fung → Fung → Burn
21. Wave → Vape → Fape → Fape → Fade → Fish
22. King → Thing → Thin → Thin → Shine → Shine → Hope
23. Cake → Fade → Fade → Fade → Free
24. Deep → Keep → Keep → Keep → Peep → Peel → Play
25. Safe → Fade → Fade → Head → Heed → Hear
26. Fast → Fast → Vast → Vast → Vast → Gast → Ghost → Goal
27. Rich → Ritch → Ritch → Litch → Litch → Lithe → Lithe → Love

By Meta AI:

Puzzles with solutions

1. Lynch → Lunch
2. Slabs → Slats
3. Tents → Tenth

Unsolvable puzzle (explanation)

1. Gnats to Gnats (target word should be different)
2. Gnome to House (Gnome is an invalid word)
3. Rheum to Rhomb ("Rhoms" is an invalid word)
4. Dewax to Dewet ("Dewet" is an invalid word)
5. Hymns to Hynes ("Hynes" is an invalid word)
6. Mangs to Manso ("Mangs" is an invalid word)
7. Urban to Urson ("Urson" is an invalid word)

Puzzle solutions with rule violations

1. Knurl → Snurl → Snult → Slunt → Flunt → Flute
2. Tryst → Tryst → Trypt → Trapt → Slapt → Slant
3. Spoke → Spork → Spart → Spate → Spelt
4. Lyric → Lyrick → Larick → Larrak → Lance
5. Wrest → Westt → Wests
6. Flint → Flins → Flins → Lints
7. Civic → Civis → Civil
8. Trope → Trops → Torps → Torse
9. Siege → Siegs → Siges → Sigma
10. Corks → Carks → Carps
11. Gorge → Gores → Gorse
12. Bunks → Bunts
13. Farad → Faras → Farms
14. Kites → Kitts → Knots
15. Lakes → Lares → Larch
16. Nards → Narcs
17. Oboes → Obol
18. Parch → Pardh → Pard
19. Quack → Quacs → Quads
20. Ranks → Ranth → Rants

By Mistral:

Puzzles with solutions

1. Hat → Hut → Cut → Cup
2. Car → Can → Van

Unsolvable puzzles (explanation)

- | | | | |
|------------|----|--------|--|
| 1. Red | to | Blue | (start and target words are different lengths) |
| 2. Man | to | Woman | (start and target words are different lengths) |
| 3. Sun | to | Moon | (start and target words are different lengths) |
| 4. Door | to | Window | (start and target words are different lengths) |
| 5. Home | to | Office | (start and target words are different lengths) |
| 6. River | to | Lake | (start and target words are different lengths) |
| 7. Cloud | to | Sky | (start and target words are different lengths) |
| 8. Green | to | Blue | (start and target words are different lengths) |
| 9. Year | to | Month | (start and target words are different lengths) |
| 10. Summer | to | Fall | (start and target words are different lengths) |
| 11. Hot | to | Cold | (start and target words are different lengths) |
| 12. Bright | to | Dark | (start and target words are different lengths) |
| 13. Day | to | Night | (start and target words are different lengths) |
| 14. Long | to | Short | (start and target words are different lengths) |
| 15. High | to | Low | (start and target words are different lengths) |

Puzzle solutions with rule violations

1. Big → Bug → Lug → Lit
2. Coal → Coil → Foil → Fire
3. Fish → Bish → Bird
4. Rain → Ran → San → Son → Snow
5. Frog → Frod → Toad

6. Tree→ Trea→ Leaf
7. Play→ Play→ Pray→ Praw→ Prow→ Wrow→ Work
8. Sand→ Sune→ Dune
9. Book→ Boke→ Poke→ Pone→ Pane→ Page
10. Winter → Winter → Winter → Winter → Winter → Winter → Spring
11. East→ East→ East→ West
12. North→ North→ North→ South
13. Fast→ Fast→ Fast→ Slow

Document 3. URL addresses of the Internet resources used in this study

1. URL address of the Word Ladder Puzzle Generating/Solving Website used in this study:
<https://ceptimus.co.uk/wordladder.php>
2. The URL address of the Merriam-Webster dictionary: <https://www.merriam-webster.com/dictionary/dictionary>

Document 4: HIPAA Privacy Rule for the Protection of Health and Mental Health Information published by the Office of Mental Health, New York State https://omh.ny.gov/omhweb/hipaa/phi_protection.html

The HIPAA Privacy Rule establishes national standards to protect individuals' medical records and other individually identifiable health information (collectively defined as “protected health information”) and applies to health plans, health care clearinghouses, and those health care providers that conduct certain health care transactions electronically. The Rule requires appropriate safeguards to protect the privacy of protected health information and sets limits and conditions on the uses and disclosures that may be made of such information without an individual’s authorization. The Rule also gives individuals rights over their protected health information, including rights to examine and obtain a copy of their health records, to direct a covered entity to transmit to a third party an electronic copy of their protected health information in an electronic health record, and to request corrections.

Basic Principles of the Privacy Rule:

1. The Privacy Rule protects all “protected health information” (PHI), including individually identifiable health or mental health information held or transmitted by a covered entity in any format, including electronic, paper, or oral statements.
2. A major purpose of the Privacy Rule is to define and limit the circumstances under which an individual's PHI may be used or disclosed by covered entities. Generally, a covered entity may not use or disclose PHI to others, except:
3. as the Privacy Rule permits or requires; or
4. as authorized by the person (or personal representative) who is the subject of the health information. A HIPAA-compliant Authorization must contain specific information required by the Privacy Rules.
5. A covered entity must provide individuals (or their personal representatives) with access to their own PHI (unless there are permitted grounds for denial) and must provide an accounting of the disclosures of their PHI to others, upon their request.

6. The Privacy Rule supersedes State law, but State laws which provide greater privacy protections, or which give individuals greater access to their own PHI remain in effect.

Permitted Uses or Disclosures of PHI Without Authorization:

Extensive provisions of the Privacy Rule describe circumstances under which covered entities are permitted to use or disclose PHI, without the authorization of the individual who is the subject of the protected information. These purposes include, but are not limited to, the following:

1. A covered entity may disclose PHI to the individual who is the subject of the information.
2. A covered entity may use and disclose protected health information for its own “treatment, payment, and health care operations.”
 - a) Treatment is the provision, coordination, or management of health care and related services for an individual, including consultation between providers and referral of an individual to another provider for health care.
 - b) Payment includes activities of a health care provider to obtain payment or to receive reimbursement for the provision of health care to an individual.
 - c) Health care operations include functions such as: (a) quality assessment and improvement; (b) competency assessment, including performance evaluation, credentialing, and accreditation; (c) medical reviews, audits, or legal services; (d) specified insurance functions; and (e) business planning, management, and general administration.
3. Permission may be obtained from the individual who is the subject of the information or by circumstances that clearly indicate an individual with capacity has the opportunity to object to the disclosure but does not express an objection. Providers may also rely on an individual's informal permission to disclose health information to an individual's family, relatives, close personal friends, or to other persons identified by the individual, limited to information directly related to such person's involvement.
4. When an individual is incapacitated or in an emergency, providers sometimes may use or disclose PHI, without authorization, when it is in the best interests of the individual, as determined by health care provider in the exercise of clinical judgment. The PHI that may be disclosed under this provision includes the patient's name, location in a health care provider's facility, and limited and general information regarding the person's condition.
5. Providers may use and disclose PHI without a person's authorization when the use or disclosure of PHI is required by law, including State statute or court order.
6. Providers generally may disclose PHI to State and Federal public health authorities to prevent or control disease, injury, or disability, and to government authorities authorized to receive reports of child abuse and neglect.
7. Providers may disclose PHI to appropriate government authorities in limited circumstances regarding victims of abuse, neglect, or domestic violence.
8. Providers may disclose PHI to health oversight agencies, (e.g., the government agency which licenses the provider), for legally authorized health oversight activities, such as audits and investigations.
9. PHI may be disclosed in a judicial or administrative proceeding if the request is pursuant to a court order, subpoena, or other lawful process.
10. Providers may generally disclose PHI to law enforcement when:

- a) Required by law, or pursuant to a court order, subpoena, or an “administrative request,” such as a subpoena or summons. The information sought must be relevant and limited to the inquiry.
 - b) To identify or locate a suspect, fugitive, material witness or missing person.
 - c) In response to a law enforcement request for information about a victim of a crime.
 - d) To alert law enforcement about criminal conduct on the premises of a HIPAA covered entity.
11. Providers may disclose PHI that they believe necessary to prevent or lessen a
- a) serious and imminent physical threat to a person or the public, when such disclosure is made to someone they believe can prevent or lessen the threat (including the target of the threat).
12. An authorization is not required to use or disclose PHI to certain government
- a) programs providing public benefits or for enrollment in government benefit
 - b) programs if the sharing of information is required or expressly authorized by statute or regulation, or other limited circumstances

“Minimum Necessary” Rule:

The minimum necessary standard requires covered entities covered entities to take reasonable steps to limit the use or disclosure of, and requests for, protected health information (PHI) to the minimum necessary to accomplish the intended purpose. The minimum necessary standard does not apply to the following:

1. Disclosures to or requests by a health care provider for treatment purposes.
2. Disclosures to the individual who is the subject of the information.
3. Uses or disclosures made pursuant to an individual’s authorization.
4. Uses or disclosures required for compliance with the Health Insurance Portability and Accountability Act (HIPAA) Administrative Simplification Rules.
5. Disclosures to the Department of Health and Human Services (HHS) when disclosure of information is required under the Privacy Rule for enforcement purposes.
6. Uses or disclosures that are required by other law.