```
# ========================
# 1. Install dependencies
# ========================
!pip install -U openai numpy pandas scipy tabulate matplotlib
```

```
Requirement already satisfied: openai in /usr/local/lib/python3.12/dist-packages (2.24.0)
Requirement already satisfied: numpy in /usr/local/lib/python3.12/dist-packages (2.4.2)
Requirement already satisfied: pandas in /usr/local/lib/python3.12/dist-packages (3.0.1)
Requirement already satisfied: scipy in /usr/local/lib/python3.12/dist-packages (1.17.1)
Requirement already satisfied: tabulate in /usr/local/lib/python3.12/dist-packages (0.9.0)
Requirement already satisfied: matplotlib in /usr/local/lib/python3.12/dist-packages (3.10.8)
Requirement already satisfied: anyio<5,>=3.5.0 in /usr/local/lib/python3.12/dist-packages (from openai) (4.12.1)
Requirement already satisfied: distro<2,>=1.7.0 in /usr/local/lib/python3.12/dist-packages (from openai) (1.9.0)
Requirement already satisfied: httpx<1,>=0.23.0 in /usr/local/lib/python3.12/dist-packages (from openai) (0.28.1)
Requirement already satisfied: jiter<1,>=0.10.0 in /usr/local/lib/python3.12/dist-packages (from openai) (0.13.0)
Requirement already satisfied: pydantic<3,>=1.9.0 in /usr/local/lib/python3.12/dist-packages (from openai) (2.12.3)
Requirement already satisfied: sniffio in /usr/local/lib/python3.12/dist-packages (from openai) (1.3.1)
Requirement already satisfied: tqdm>4 in /usr/local/lib/python3.12/dist-packages (from openai) (4.67.3)
Requirement already satisfied: typing-extensions<5,>=4.11 in /usr/local/lib/python3.12/dist-packages (from openai) (4.15.0)
Requirement already satisfied: python-dateutil>=2.8.2 in /usr/local/lib/python3.12/dist-packages (from pandas) (2.9.0.post0)
Requirement already satisfied: contourpy>=1.0.1 in /usr/local/lib/python3.12/dist-packages (from matplotlib) (1.3.3)
Requirement already satisfied: cycler>=0.10 in /usr/local/lib/python3.12/dist-packages (from matplotlib) (0.12.1)
Requirement already satisfied: fonttools>=4.22.0 in /usr/local/lib/python3.12/dist-packages (from matplotlib) (4.61.1)
Requirement already satisfied: kiwisolver>=1.3.1 in /usr/local/lib/python3.12/dist-packages (from matplotlib) (1.4.9)
Requirement already satisfied: packaging>=20.0 in /usr/local/lib/python3.12/dist-packages (from matplotlib) (26.0)
Requirement already satisfied: pillow>=8 in /usr/local/lib/python3.12/dist-packages (from matplotlib) (11.3.0)
Requirement already satisfied: pyparsing>=3 in /usr/local/lib/python3.12/dist-packages (from matplotlib) (3.3.2)
Requirement already satisfied: idna>=2.8 in /usr/local/lib/python3.12/dist-packages (from anyio<5,>=3.5.0->openai) (3.11)
Requirement already satisfied: certifi in /usr/local/lib/python3.12/dist-packages (from httpx<1,>=0.23.0->openai) (2026.1.4)
Requirement already satisfied: httpcore==1.* in /usr/local/lib/python3.12/dist-packages (from httpx<1,>=0.23.0->openai) (1.0.9)
Requirement already satisfied: h11>=0.16 in /usr/local/lib/python3.12/dist-packages (from httpcore==1.*->httpx<1,>=0.23.0->openai) (0.16
Requirement already satisfied: annotated-types>=0.6.0 in /usr/local/lib/python3.12/dist-packages (from pydantic<3,>=1.9.0->openai) (0.7.
Requirement already satisfied: pydantic-core==2.41.4 in /usr/local/lib/python3.12/dist-packages (from pydantic<3,>=1.9.0->openai) (2.41.
Requirement already satisfied: typing-inspection>=0.4.2 in /usr/local/lib/python3.12/dist-packages (from pydantic<3,>=1.9.0->openai) (0.
Requirement already satisfied: six>=1.5 in /usr/local/lib/python3.12/dist-packages (from python-dateutil>=2.8.2->pandas) (1.17.0)
```

```
# ========================
# 2. Import library
# ========================
import os
import time
import json
import math
import random
import numpy as np
import pandas as pd
import matplotlib.pyplot as plt

from openai import OpenAI
from scipy.stats import norm
from tabulate import tabulate
```

```
# ========================================================
# 2.Configure DeepSeek API
# ========================================================

DEEPSEEK_API_KEY = "sk-341d520715c144fd92b2b56037123a46".strip()

if not DEEPSEEK_API_KEY:
        raise ValueError("DEEPSEEK_API_KEY is empty; please fill it in first.")

client = OpenAI(
        api_key=DEEPSEEK_API_KEY,
        base_url="https://api.deepseek.com"
)

MODEL_NAME = "deepseek-chat"

print("DeepSeek client ready")
print("model:", MODEL_NAME)
print("key length:", len(DEEPSEEK_API_KEY))
print("key prefix:", DEEPSEEK_API_KEY[:5])
```

```
DeepSeek client ready
model: deepseek-chat
key length: 35
key prefix: sk-34
```

```
# ========================================================
# 3. Global Experimental Parameters
# ========================================================
```

```python
# Start with a small-scale test to facilitate assignment submission and debugging.
N_LIST = [1, 3]
BLOCKS = 2

# If you want to make the result more stable later, you can change it to:
# BLOCKS = 5

ALPHABET = "bcdfghjklnpqrstvwxyz"
SEQ_LENGTH = 24
MATCHES = 8

RANDOM_SEED = 42
random.seed(RANDOM_SEED)
np.random.seed(RANDOM_SEED)

print("N_LIST =", N_LIST)
print("BLOCKS =", BLOCKS)
print("SEQ_LENGTH =", SEQ_LENGTH)
print("MATCHES =", MATCHES)
```

```
N_LIST = [1, 3]
BLOCKS = 2
SEQ_LENGTH = 24
MATCHES = 8
```

```python
# =========================
# Generate verbal n-back sequences
# =========================
def generate_nback_sequences(n, alphabet, seq_length, matches, num_sequences):
    sequences = []

    for _ in range(num_sequences):
        seq = []
        conditions = []

        match_positions = random.sample(range(n, seq_length), matches)
        match_positions.sort()

        for i in range(seq_length):
            if i in match_positions:
                # Forced construction of match
                seq.append(seq[i - n])
                conditions.append("m")
            else:
                # Construct a non-match to avoid unexpected n-back matches.
                random_letter = random.choice(alphabet)
                while i >= n and random_letter == seq[i - n]:
                    random_letter = random.choice(alphabet)

                seq.append(random_letter)
                conditions.append("-")

        sequences.append(("".join(seq), "".join(conditions)))

    return sequences


def build_all_trials(n_list, blocks, alphabet, seq_length, matches):
    all_trials = {}

    for n in n_list:
        sequences = generate_nback_sequences(
            n=n,
            alphabet=alphabet,
            seq_length=seq_length,
            matches=matches,
            num_sequences=blocks
        )

        for b, (seq, cond) in enumerate(sequences):
            trials = []
            for i in range(len(seq)):
                trials.append({
                    "stimulus": seq[i],
                    "target": cond[i],
                    "response": "",
                    "correct": None,
                    "rt": None
                })

            all_trials[f"{n}back_{b}"] = trials
    return all_trials


all_trials = build_all_trials(
    n_list=N_LIST,
    blocks=BLOCKS,
    alphabet=ALPHABET,
    seq_length=SEQ_LENGTH,
    matches=MATCHES
)

print("Data preparation complete.")
print("Keys example:", list(all_trials.keys())[:3])
```

```
Data preparation complete.
Keys example: ['1back_0', '1back_1', '3back_0']
```

```
# =========================
# 5. DeepSeek function calls (stable version)
# =========================
def normalize_response(text):
        """
        Try to normalize the model output to 'm' or '-'.
        """
        if text is None:
                return None

        text = str(text).strip().lower()

        # Exact Match
        if text == "m":
                return "m"
        if text == "-":
                return "-"

        # Common multiple output scenarios
        text = text.replace(" ", "")
        if text.startswith("m"):
                return "m"
        if text.startswith("-"):
                return "-"

        # Iterate through the list to find the first valid character
        for ch in text:
                if ch in ["m", "-"]:
                        return ch

        return None


def get_model_response(messages, model_name, temperature, max_retries=3, sleep_seconds=2):
        if "client" not in globals():
                raise ValueError("The client has not been initialized yet. Please run the API configuration section first

        last_error = None

        for attempt in range(max_retries):
                try:
                        start_time = time.time()

                        completion = client.chat.completions.create(
                                model=model_name,
                                messages=messages,
                                temperature=temperature,
                                max_tokens=5
                        )

                        response_time = time.time() - start_time
                        raw_text = completion.choices[0].message.content
                        response = normalize_response(raw_text)

                        return response, raw_text, response_time

                except Exception as e:
                        last_error = e
                        print(f"[API ERROR] attempt {attempt+1}/{max_retries}: {e}")
                        time.sleep(sleep_seconds)

        raise RuntimeError(f"The API kept failing, eventually resulting in an error.: {last_error}")
```

```
# ========================
# 6. Run a single n-back task (stable version)
# ========================
def run_nback_task(all_trials, n, blocks, model_name, temperature, output_file, sleep_between_blocks=1):
    if n == 1:
        task_instruction = (
            "You are asked to perform a 1-back task. "
            "You will see a sequence of letters one by one. "
            "Respond with 'm' whenever the current letter is the same as the previous letter, "
            "and '-' otherwise. Only output 'm' or '-'. No explanation."
        )
    elif n == 2:
        task_instruction = (
            "You are asked to perform a 2-back task. "
            "You will see a sequence of letters one by one. "
            "Respond with 'm' whenever the current letter is the same as the letter two steps ago, "
            "and '-' otherwise. Only output 'm' or '-'. No explanation."
        )
    elif n == 3:
        task_instruction = (
            "You are asked to perform a 3-back task. "
            "You will see a sequence of letters one by one. "
            "Respond with 'm' whenever the current letter is the same as the letter three steps ago, "
            "and '-' otherwise. Only output 'm' or '-'. No explanation."
        )
    else:
        raise ValueError("Currently only supports n=1/2/3")

    for b in range(blocks):
        trial_key = f"{n}back_{b}"
        messages = [{"role": "system", "content": task_instruction}]

        print(f"\n========== Running {trial_key} ==========")

        for i, trial in enumerate(all_trials[trial_key]):
            stimulus = trial["stimulus"]
            target = trial["target"]

            print(f"block {b}, trial {i}: stimulus={stimulus}, target={target}")

            messages.append({"role": "user", "content": stimulus})

            try:
                response, raw_text, rt = get_model_response(
                    messages=messages,
                    model_name=model_name,
                    temperature=temperature
                )

                trial["rt"] = rt
                trial["raw_output"] = raw_text

                # If the parsing still fails, provide a default value to avoid interrupting the entire e
                if response not in ["m", "-"]:
                    print(f"[WARNING] Unable to recognize output, raw={raw_text}, Default is recorded as '-
                    response = "-"

                trial["response"] = response
                trial["correct"] = (response == target)

                print(f"model raw: {raw_text}")
                print(f"parsed: {response}")
                print(f"rt: {rt:.2f}s")
                print("correct" if trial["correct"] else "incorrect")
                print("------------------------------------")

                messages.append({"role": "assistant", "content": response})

            except Exception as e:
                print(f"[TRIAL ERROR] block {b}, trial {i}: {e}")

                trial["rt"] = None
                trial["raw_output"] = str(e)
                trial["response"] = "ERROR"
                trial["correct"] = False

                # To avoid interrupting the entire experiment, a default answer is added to the context.
                messages.append({"role": "assistant", "content": "-"})

        # Save the code after each block to prevent data loss if the process is interrupted.
        with open(output_file, "w", encoding="utf-8") as f:
            json.dump(all_trials, f, ensure_ascii=False, indent=2)
        print(f"[AUTO-SAVED] {output_file}")
        time.sleep(sleep_between_blocks)

    return all_trials
```

```
# ========================================================
# 7. Statistical Results
# ========================================================

def compute_summary_stats(all_trials, n_list, blocks):
    summary_stats = {}
    raw_data = {}

    for n in n_list:
        hit_rate = []
        false_alarm_rate = []
        accuracy = []
        response_time = []
        d_prime = []

        for b in range(blocks):
            trials = all_trials[f"{n}back_{b}"]

            hits = 0
            false_alarms = 0
            total_targets = 0
            total_lures = 0
            total_rt = 0

            for trial in trials:
                if trial["target"] == "m":
                    total_targets += 1
                    if trial["correct"]:
                        hits += 1
                        if trial["rt"] is not None:
                            total_rt += trial["rt"]
                else:
                    total_lures += 1
                    if trial["response"] == "m":
                        false_alarms += 1

            hr = (hits / total_targets) * 100 if total_targets > 0 else np.nan
            far = (false_alarms / total_lures) * 100 if total_lures > 0 else np.nan
            acc = ((hits + (total_lures - false_alarms)) / (total_targets + total_lures)) * 100

            hit_rate_adjusted = np.clip(hits / total_targets, 0.01, 0.99) if total_targets > 0 else np.nan
            false_alarm_rate_adjusted = np.clip(false_alarms / total_lures, 0.01, 0.99) if total_lures > 0 else

            if not np.isnan(hit_rate_adjusted) and not np.isnan(false_alarm_rate_adjusted):
                dp = abs(norm.ppf(hit_rate_adjusted) - norm.ppf(false_alarm_rate_adjusted))
            else:
                dp = np.nan

            mean_rt = total_rt / hits if hits > 0 else np.nan

            hit_rate.append(hr)
            false_alarm_rate.append(far)
            accuracy.append(acc)
            response_time.append(mean_rt)
            d_prime.append(dp)

        raw_data[n] = {
            "hit_rate": hit_rate,
            "false_alarm_rate": false_alarm_rate,
            "accuracy": accuracy,
            "response_time": response_time,
            "d_prime": d_prime
        }

        summary_stats[n] = {
            "hit_rate": {
                "mean": np.nanmean(hit_rate),
                "stderr": np.nanstd(hit_rate, ddof=1) / math.sqrt(blocks) if blocks > 1 else 0
            },
            "false_alarm_rate": {
                "mean": np.nanmean(false_alarm_rate),
                "stderr": np.nanstd(false_alarm_rate, ddof=1) / math.sqrt(blocks) if blocks > 1 else 0
            },
            "accuracy": {
                "mean": np.nanmean(accuracy),
                "stderr": np.nanstd(accuracy, ddof=1) / math.sqrt(blocks) if blocks > 1 else 0
```

```
                    },
                    "d_prime": {
                            "mean": np.nanmean(d_prime),
                            "stderr": np.nanstd(d_prime, ddof=1) / math.sqrt(blocks) if blocks > 1 else 0
                    }
            }

        return summary_stats, raw_data


def create_summary_table(summary_stats, n_list):
        headers = ["N-back", "Hit Rate (%)", "False Alarm Rate (%)", "Accuracy (%)", "D Prime"]
        rows = []

        for n in n_list:
                rows.append([
                        f"{n}-back",
                        f"{summary_stats[n]['hit_rate']['mean']:.2f} ± {summary_stats[n]['hit_rate']['stderr']:.2f}",
                        f"{summary_stats[n]['false_alarm_rate']['mean']:.2f} ± {summary_stats[n]['false_alarm_rate']['stderr']:.2f}"
                        f"{summary_stats[n]['accuracy']['mean']:.2f} ± {summary_stats[n]['accuracy']['stderr']:.2f}",
                        f"{summary_stats[n]['d_prime']['mean']:.2f} ± {summary_stats[n]['d_prime']['stderr']:.2f}",
                ])

        df = pd.DataFrame(rows, columns=headers)
        print(tabulate(df.values, headers=df.columns, tablefmt="github"))
        return df
```

```
# ========================================================
# 8. Plotting function
# ========================================================

def plot_accuracy(summary_stats, n_list, model_name, temperature):
        x = [str(n) for n in n_list]
        y = [summary_stats[n]["accuracy"]["mean"] for n in n_list]
        yerr = [summary_stats[n]["accuracy"]["stderr"] for n in n_list]

        plt.figure(figsize=(6, 4))
        plt.bar(x, y, yerr=yerr)
        plt.xlabel("N-back")
        plt.ylabel("Accuracy (%)")
        plt.title(f"Verbal N-Back Accuracy ({model_name}, temp={temperature})")
        plt.show()
```

```
# ========================================================
# 9. Run a single experiment (one temperature).
# ========================================================

def run_experiment_for_temperature(temperature, model_name, n_list, blocks):
        output_file = f"all_trials_verbal_temp{temperature}.json"

        print("\n" + "=" * 60)
        print(f"开始运行实验：temperature = {temperature}")
        print("=" * 60)

# Regenerate the same set of trial structures for each temperature

# Note: To ensure reproducibility, the seed is fixed again.
        random.seed(RANDOM_SEED)
        np.random.seed(RANDOM_SEED)

        all_trials = build_all_trials(
                n_list=n_list,
                blocks=blocks,
                alphabet=ALPHABET,
                seq_length=SEQ_LENGTH,
                matches=MATCHES
        )

        for n in n_list:
                all_trials = run_nback_task(
                        all_trials=all_trials,
                        n=n,
                        blocks=blocks,
                        model_name=model_name,
                        temperature=temperature,
                        output_file=output_file,
                        sleep_between_blocks=1
                )

        with open(output_file, "w", encoding="utf-8") as f:
                json.dump(all_trials, f, ensure_ascii=False, indent=2)
        print(f"\nThe experiment is complete, and the results have been saved to: {output_file}")

        summary_stats, raw_data = compute_summary_stats(all_trials, n_list, blocks)
        summary_df = create_summary_table(summary_stats, n_list)
        plot_accuracy(summary_stats, n_list, model_name, temperature)

        return {
                "temperature": temperature,
                "output_file": output_file,
                "all_trials": all_trials,
                "summary_stats": summary_stats,
                "summary_df": summary_df,
                "raw_data": raw_data
        }
```

```
# ========================================================
# 10. First, run a minimal API test (it's recommended to run it first).
# ========================================================

test_messages = [
        {"role": "system", "content": "Reply with only m or -."},
        {"role": "user", "content": "x"}
]

completion = client.chat.completions.create(
        model=MODEL_NAME,
        messages=test_messages,
        temperature=0,
        max_tokens=5
)

print("API test output:", completion.choices[0].message.content)
```

```
API test output: -
```

```
# ========================================================
# 11. Conduct two sets of experiments.
#         baseline: temp = 1
#         modification: temp = 0
# ========================================================

result_temp1 = run_experiment_for_temperature(
        temperature=1,
        model_name=MODEL_NAME,
        n_list=N_LIST,
        blocks=BLOCKS
)

result_temp0 = run_experiment_for_temperature(
        temperature=0,
        model_name=MODEL_NAME,
        n_list=N_LIST,
        blocks=BLOCKS
)
```

```
============================================================
开始运行实验：temperature = 1
============================================================

========== Running 1back_0 ==========
block 0, trial 0: stimulus=x, target=-
model raw: -
parsed: -
rt: 1.20s
correct
------------------------------------
block 0, trial 1: stimulus=x, target=m
model raw: m
parsed: m
rt: 1.30s
correct
------------------------------------
block 0, trial 2: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.60s
correct
------------------------------------
block 0, trial 3: stimulus=y, target=-
model raw: -
parsed: -
rt: 1.43s
correct
------------------------------------
block 0, trial 4: stimulus=y, target=m
model raw: m
parsed: m
rt: 1.02s
correct
------------------------------------
block 0, trial 5: stimulus=y, target=m
model raw: m
parsed: m
rt: 1.54s
correct
------------------------------------
block 0, trial 6: stimulus=s, target=-
model raw: -
parsed: -
rt: 1.46s
correct
------------------------------------
block 0, trial 7: stimulus=c, target=-
model raw: -
parsed: -
rt: 1.14s
correct
------------------------------------
block 0, trial 8: stimulus=c, target=m
model raw: m
parsed: m
rt: 1.45s
correct
------------------------------------
block 0, trial 9: stimulus=c, target=m
model raw: m
parsed: m
rt: 1.21s
correct
------------------------------------
block 0, trial 10: stimulus=b, target=-
model raw: -
parsed: -
rt: 1.23s
correct
------------------------------------
block 0, trial 11: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.20s
correct
------------------------------------
block 0, trial 12: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.25s
correct
------------------------------------
block 0, trial 13: stimulus=k, target=-
```

```
model raw: -
parsed: -
rt: 1.56s
correct
------------------------------------
block 0, trial 14: stimulus=w, target=-
model raw: -
parsed: -
rt: 1.52s
correct
------------------------------------
block 0, trial 15: stimulus=z, target=-
model raw: -
parsed: -
rt: 1.76s
correct
------------------------------------
block 0, trial 16: stimulus=b, target=-
model raw: -
parsed: -
rt: 1.28s
correct
------------------------------------
block 0, trial 17: stimulus=x, target=-
model raw: -
parsed: -
rt: 1.69s
correct
------------------------------------
block 0, trial 18: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.28s
correct
------------------------------------
block 0, trial 19: stimulus=j, target=m
model raw: m
parsed: m
rt: 1.80s
correct
------------------------------------
block 0, trial 20: stimulus=x, target=-
model raw: -
parsed: -
rt: 1.26s
correct
------------------------------------
block 0, trial 21: stimulus=x, target=m
model raw: m
parsed: m
rt: 2.80s
correct
------------------------------------
block 0, trial 22: stimulus=x, target=m
model raw: m
parsed: m
rt: 1.77s
correct
------------------------------------
block 0, trial 23: stimulus=s, target=-
model raw: -
parsed: -
rt: 1.27s
correct
------------------------------------
[AUTO-SAVED] all_trials_verbal_temp1.json

========== Running 1back_1 ==========
block 1, trial 0: stimulus=l, target=-
model raw: -
parsed: -
rt: 1.32s
correct
------------------------------------
block 1, trial 1: stimulus=l, target=m
model raw: m
parsed: m
rt: 1.58s
correct
------------------------------------
block 1, trial 2: stimulus=g, target=-
model raw: -
parsed: -
rt: 1.48s
correct
------------------------------------
```

```
block 1, trial 3: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.42s
correct
------------------------------------
block 1, trial 4: stimulus=p, target=-
model raw: -
parsed: -
rt: 1.28s
correct
------------------------------------
block 1, trial 5: stimulus=f, target=-
model raw: -
parsed: -
rt: 1.05s
correct
------------------------------------
block 1, trial 6: stimulus=f, target=m
model raw: m
parsed: m
rt: 1.00s
correct
------------------------------------
block 1, trial 7: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.31s
correct
------------------------------------
block 1, trial 8: stimulus=d, target=m
model raw: m
parsed: m
rt: 1.38s
correct
------------------------------------
block 1, trial 9: stimulus=d, target=m
model raw: m
parsed: m
rt: 1.50s
correct
------------------------------------
block 1, trial 10: stimulus=r, target=-
model raw: -
parsed: -
rt: 1.60s
correct
------------------------------------
block 1, trial 11: stimulus=r, target=m
model raw: m
parsed: m
rt: 1.64s
correct
------------------------------------
block 1, trial 12: stimulus=f, target=-
model raw: -
parsed: -
rt: 1.29s
correct
------------------------------------
block 1, trial 13: stimulus=q, target=-
model raw: -
parsed: -
rt: 1.43s
correct
------------------------------------
block 1, trial 14: stimulus=q, target=m
model raw: m
parsed: m
rt: 1.19s
correct
------------------------------------
block 1, trial 15: stimulus=q, target=m
model raw: m
parsed: m
rt: 1.17s
correct
------------------------------------
block 1, trial 16: stimulus=z, target=-
model raw: -
parsed: -
rt: 1.57s
correct
------------------------------------
block 1, trial 17: stimulus=l, target=-
```

```
model raw: -
parsed: -
rt: 1.54s
correct
------------------------------------
block 1, trial 18: stimulus=c, target=-
model raw: -
parsed: -
rt: 1.67s
correct
------------------------------------
block 1, trial 19: stimulus=c, target=m
model raw: m
parsed: m
rt: 1.66s
correct
------------------------------------
block 1, trial 20: stimulus=t, target=-
model raw: -
parsed: -
rt: 1.22s
correct
------------------------------------
block 1, trial 21: stimulus=x, target=-
model raw: -
parsed: -
rt: 1.12s
correct
------------------------------------
block 1, trial 22: stimulus=f, target=-
model raw: -
parsed: -
rt: 1.39s
correct
------------------------------------
block 1, trial 23: stimulus=r, target=-
model raw: -
parsed: -
rt: 1.87s
correct
------------------------------------
[AUTO-SAVED] all_trials_verbal_temp1.json

========= Running 3back_0 =========
block 0, trial 0: stimulus=k, target=-
model raw: -
parsed: -
rt: 2.29s
correct
------------------------------------
block 0, trial 1: stimulus=n, target=-
model raw: -
parsed: -
rt: 1.69s
correct
------------------------------------
block 0, trial 2: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.46s
correct
------------------------------------
block 0, trial 3: stimulus=k, target=m
model raw: m
parsed: m
rt: 1.49s
correct
------------------------------------
block 0, trial 4: stimulus=k, target=-
model raw: -
parsed: -
rt: 1.59s
correct
------------------------------------
block 0, trial 5: stimulus=d, target=m
model raw: -
parsed: -
rt: 1.67s
incorrect
------------------------------------
block 0, trial 6: stimulus=f, target=-
model raw: -
parsed: -
rt: 1.81s
correct
------------------------------------
```

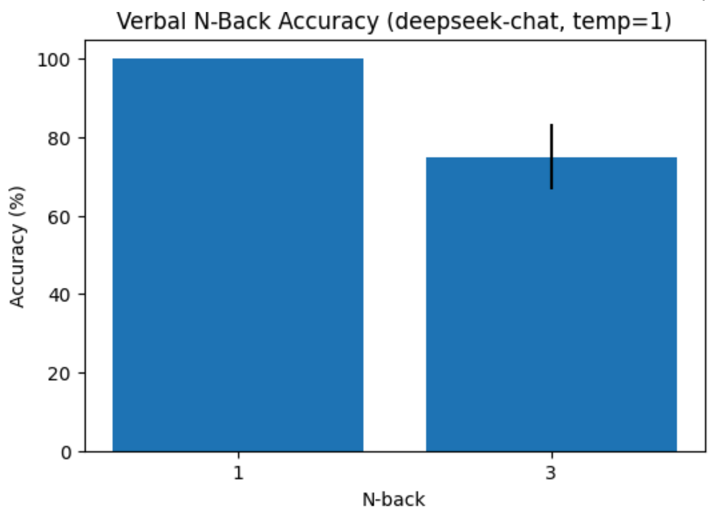
```
block 0, trial 7: stimulus=r, target=-
model raw: -
parsed: -
rt: 1.61s
correct
------------------------------------
block 0, trial 8: stimulus=l, target=-
model raw: -
parsed: -
rt: 1.48s
correct
------------------------------------
block 0, trial 9: stimulus=f, target=m
model raw: m
parsed: m
rt: 1.67s
correct
------------------------------------
block 0, trial 10: stimulus=t, target=-
model raw: -
parsed: -
rt: 1.42s
correct
------------------------------------
block 0, trial 11: stimulus=q, target=-
model raw: -
parsed: -
rt: 1.70s
correct
------------------------------------
block 0, trial 12: stimulus=f, target=m
model raw: -
parsed: -
rt: 1.74s
incorrect
------------------------------------
block 0, trial 13: stimulus=t, target=m
model raw: -
parsed: -
rt: 1.73s
incorrect
------------------------------------
block 0, trial 14: stimulus=q, target=m
model raw: m
parsed: m
rt: 1.57s
correct
------------------------------------
block 0, trial 15: stimulus=h, target=-
model raw: -
parsed: -
rt: 1.77s
correct
------------------------------------
block 0, trial 16: stimulus=q, target=-
model raw: -
parsed: -
rt: 1.78s
correct
------------------------------------
block 0, trial 17: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.77s
correct
------------------------------------
block 0, trial 18: stimulus=l, target=-
model raw: -
parsed: -
rt: 1.71s
correct
------------------------------------
block 0, trial 19: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.53s
correct
------------------------------------
block 0, trial 20: stimulus=j, target=m
model raw: -
parsed: -
rt: 1.96s
incorrect
------------------------------------
block 0, trial 21: stimulus=z, target=-
```

```
model raw: 
parsed: -
rt: 1.64s
correct
------------------------------------
block 0, trial 22: stimulus=h, target=-
model raw: -
parsed: -
rt: 1.43s
correct
------------------------------------
block 0, trial 23: stimulus=j, target=m
model raw: m
parsed: m
rt: 1.77s
correct
------------------------------------
[AUTO-SAVED] all_trials_verbal_temp1.json

========== Running 3back_1 ==========
block 1, trial 0: stimulus=x, target=-
model raw: -
parsed: -
rt: 1.32s
correct
------------------------------------
block 1, trial 1: stimulus=k, target=-
model raw: -
parsed: -
rt: 1.76s
correct
------------------------------------
block 1, trial 2: stimulus=p, target=-
model raw: -
parsed: -
rt: 1.65s
correct
------------------------------------
block 1, trial 3: stimulus=c, target=-
model raw: -
parsed: -
rt: 1.46s
correct
------------------------------------
block 1, trial 4: stimulus=c, target=-
model raw: -
parsed: -
rt: 1.72s
correct
------------------------------------
block 1, trial 5: stimulus=r, target=-
model raw: -
parsed: -
rt: 1.64s
correct
------------------------------------
block 1, trial 6: stimulus=l, target=-
model raw: -
parsed: -
rt: 1.53s
correct
------------------------------------
block 1, trial 7: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.73s
correct
------------------------------------
block 1, trial 8: stimulus=r, target=m
model raw: -
parsed: -
rt: 1.70s
incorrect
------------------------------------
block 1, trial 9: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.61s
correct
------------------------------------
block 1, trial 10: stimulus=d, target=m
model raw: -
parsed: -
rt: 1.74s
incorrect
------------------------------------
```

```
block 1, trial 11: stimulus=r, target=m
model raw: -
parsed: -
rt: 1.56s
incorrect
------------------------------------
block 1, trial 12: stimulus=y, target=-
model raw: -
parsed: -
rt: 1.53s
correct
------------------------------------
block 1, trial 13: stimulus=d, target=m
model raw: -
parsed: -
rt: 1.33s
incorrect
------------------------------------
block 1, trial 14: stimulus=p, target=-
model raw: -
parsed: -
rt: 1.94s
correct
------------------------------------
block 1, trial 15: stimulus=y, target=m
model raw: -
parsed: -
rt: 1.53s
incorrect
------------------------------------
block 1, trial 16: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.44s
correct
------------------------------------
block 1, trial 17: stimulus=p, target=m
model raw: -
parsed: -
rt: 1.30s
incorrect
------------------------------------
block 1, trial 18: stimulus=v, target=-
model raw: -
parsed: -
rt: 1.65s
correct
------------------------------------
block 1, trial 19: stimulus=r, target=-
model raw: -
parsed: -
rt: 1.63s
correct
------------------------------------
block 1, trial 20: stimulus=p, target=m
model raw: -
parsed: -
rt: 1.55s
incorrect
------------------------------------
block 1, trial 21: stimulus=t, target=-
model raw: -
parsed: -
rt: 1.39s
correct
------------------------------------
block 1, trial 22: stimulus=g, target=-
model raw: -
parsed: -
rt: 2.07s
correct
------------------------------------
block 1, trial 23: stimulus=p, target=m
model raw: -
parsed: -
rt: 1.41s
incorrect
------------------------------------
[AUTO-SAVED] all_trials_verbal_temp1.json

The experiment is complete, and the results have been saved to: all_trials_verbal_temp1.json
| N-back   | Hit Rate (%)   | False Alarm Rate (%)   | Accuracy (%)   | D Prime    |
|----------|----------------|------------------------|----------------|------------|
| 1-back   | 100.00 ± 0.00  | 0.00 ± 0.00            | 100.00 ± 0.00  | 4.65 ± 0.00 |
| 3-back   | 25.00 ± 25.00  | 0.00 ± 0.00            | 75.00 ± 8.33   | 1.16 ± 1.16 |
```



```
============================================================
开始运行实验：temperature = 0
============================================================

========== Running 1back_0 ==========
block 0, trial 0: stimulus=x, target=-
model raw: -
parsed: -
rt: 1.73s
correct
------------------------------------
block 0, trial 1: stimulus=x, target=m
model raw: -
parsed: -
rt: 1.91s
incorrect
------------------------------------
block 0, trial 2: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.66s
correct
------------------------------------
block 0, trial 3: stimulus=y, target=-
model raw: -
parsed: -
rt: 1.41s
correct
------------------------------------
block 0, trial 4: stimulus=y, target=m
model raw: m
parsed: m
rt: 1.49s
correct
------------------------------------
block 0, trial 5: stimulus=y, target=m
model raw: m
parsed: m
rt: 1.46s
correct
------------------------------------
block 0, trial 6: stimulus=s, target=-
model raw: -
parsed: -
rt: 1.79s
correct
------------------------------------
block 0, trial 7: stimulus=c, target=-
model raw: -
parsed: -
rt: 1.47s
correct
------------------------------------
block 0, trial 8: stimulus=c, target=m
model raw: m
parsed: m
rt: 1.64s
correct
------------------------------------
block 0, trial 9: stimulus=c, target=m
model raw: m
parsed: m
rt: 1.67s
correct
```

```
------------------------------------
block 0, trial 10: stimulus=b, target=-
model raw: -
parsed: -
rt: 1.51s
correct
------------------------------------
block 0, trial 11: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.74s
correct
------------------------------------
block 0, trial 12: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.78s
correct
------------------------------------
block 0, trial 13: stimulus=k, target=-
model raw: -
parsed: -
rt: 1.61s
correct
------------------------------------
block 0, trial 14: stimulus=w, target=-
model raw: -
parsed: -
rt: 1.90s
correct
------------------------------------
block 0, trial 15: stimulus=z, target=-
model raw: -
parsed: -
rt: 1.38s
correct
------------------------------------
block 0, trial 16: stimulus=b, target=-
model raw: -
parsed: -
rt: 1.56s
correct
------------------------------------
block 0, trial 17: stimulus=x, target=-
model raw: -
parsed: -
rt: 1.41s
correct
------------------------------------
block 0, trial 18: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.71s
correct
------------------------------------
block 0, trial 19: stimulus=j, target=m
model raw: m
parsed: m
rt: 1.45s
correct
------------------------------------
block 0, trial 20: stimulus=x, target=-
model raw: -
parsed: -
rt: 1.45s
correct
------------------------------------
block 0, trial 21: stimulus=x, target=m
model raw: m
parsed: m
rt: 1.67s
correct
------------------------------------
block 0, trial 22: stimulus=x, target=m
model raw: m
parsed: m
rt: 1.29s
correct
------------------------------------
block 0, trial 23: stimulus=s, target=-
model raw: -
parsed: -
rt: 1.41s
correct
------------------------------------
```

```
[AUTO-SAVED] all_trials_verbal_temp0.json

========== Running 1back_1 ==========
block 1, trial 0: stimulus=l, target=-
model raw: -
parsed: -
rt: 1.11s
correct
------------------------------------
block 1, trial 1: stimulus=l, target=m
model raw: -
parsed: -
rt: 1.59s
incorrect
------------------------------------
block 1, trial 2: stimulus=g, target=-
model raw: -
parsed: -
rt: 1.54s
correct
------------------------------------
block 1, trial 3: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.44s
correct
------------------------------------
block 1, trial 4: stimulus=p, target=-
model raw: -
parsed: -
rt: 1.31s
correct
------------------------------------
block 1, trial 5: stimulus=f, target=-
model raw: -
parsed: -
rt: 1.60s
correct
------------------------------------
block 1, trial 6: stimulus=f, target=m
model raw: m
parsed: m
rt: 1.41s
correct
------------------------------------
block 1, trial 7: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.39s
correct
------------------------------------
block 1, trial 8: stimulus=d, target=m
model raw: m
parsed: m
rt: 1.24s
correct
------------------------------------
block 1, trial 9: stimulus=d, target=m
model raw: m
parsed: m
rt: 1.28s
correct
------------------------------------
block 1, trial 10: stimulus=r, target=-
model raw: -
parsed: -
rt: 1.11s
correct
------------------------------------
block 1, trial 11: stimulus=r, target=m
model raw: m
parsed: m
rt: 1.61s
correct
------------------------------------
block 1, trial 12: stimulus=f, target=-
model raw: -
parsed: -
rt: 1.14s
correct
------------------------------------
block 1, trial 13: stimulus=q, target=-
model raw: -
parsed: -
rt: 1.43s
correct
```

```
------------------------------------
block 1, trial 14: stimulus=q, target=m
model raw: m
parsed: m
rt: 1.29s
correct
------------------------------------
block 1, trial 15: stimulus=q, target=m
model raw: m
parsed: m
rt: 1.51s
correct
------------------------------------
block 1, trial 16: stimulus=z, target=-
model raw: -
parsed: -
rt: 1.28s
correct
------------------------------------
block 1, trial 17: stimulus=l, target=-
model raw: -
parsed: -
rt: 1.56s
correct
------------------------------------
block 1, trial 18: stimulus=c, target=-
model raw: -
parsed: -
rt: 1.16s
correct
------------------------------------
block 1, trial 19: stimulus=c, target=m
model raw: m
parsed: m
rt: 1.24s
correct
------------------------------------
block 1, trial 20: stimulus=t, target=-
model raw: -
parsed: -
rt: 1.56s
correct
------------------------------------
block 1, trial 21: stimulus=x, target=-
model raw: -
parsed: -
rt: 1.83s
correct
------------------------------------
block 1, trial 22: stimulus=f, target=-
model raw: -
parsed: -
rt: 1.54s
correct
------------------------------------
block 1, trial 23: stimulus=r, target=-
model raw: -
parsed: -
rt: 1.21s
correct
------------------------------------
[AUTO-SAVED] all_trials_verbal_temp0.json

========== Running 3back_0 ==========
block 0, trial 0: stimulus=k, target=-
model raw: -
parsed: -
rt: 1.30s
correct
------------------------------------
block 0, trial 1: stimulus=n, target=-
model raw: -
parsed: -
rt: 1.34s
correct
------------------------------------
block 0, trial 2: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.50s
correct
------------------------------------
block 0, trial 3: stimulus=k, target=m
model raw: m
parsed: m
```

```
rt: 1.11s
correct
------------------------------------
block 0, trial 4: stimulus=k, target=-
model raw: -
parsed: -
rt: 1.45s
correct
------------------------------------
block 0, trial 5: stimulus=d, target=m
model raw: -
parsed: -
rt: 1.59s
incorrect
------------------------------------
block 0, trial 6: stimulus=f, target=-
model raw: -
parsed: -
rt: 1.55s
correct
------------------------------------
block 0, trial 7: stimulus=r, target=-
model raw: -
parsed: -
rt: 1.73s
correct
------------------------------------
block 0, trial 8: stimulus=l, target=-
model raw: -
parsed: -
rt: 1.73s
correct
------------------------------------
block 0, trial 9: stimulus=f, target=m
model raw: -
parsed: -
rt: 1.53s
incorrect
------------------------------------
block 0, trial 10: stimulus=t, target=-
model raw: -
parsed: -
rt: 1.36s
correct
------------------------------------
block 0, trial 11: stimulus=q, target=-
model raw: -
parsed: -
rt: 1.44s
correct
------------------------------------
block 0, trial 12: stimulus=f, target=m
model raw: m
parsed: m
rt: 1.72s
correct
------------------------------------
block 0, trial 13: stimulus=t, target=m
model raw: -
parsed: -
rt: 1.47s
incorrect
------------------------------------
block 0, trial 14: stimulus=q, target=m
model raw: m
parsed: m
rt: 1.76s
correct
------------------------------------
block 0, trial 15: stimulus=h, target=-
model raw: -
parsed: -
rt: 1.19s
correct
------------------------------------
block 0, trial 16: stimulus=q, target=-
model raw: -
parsed: -
rt: 1.85s
correct
------------------------------------
block 0, trial 17: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.31s
correct
```

```
------------------------------------
block 0, trial 18: stimulus=l, target=-
model raw: -
parsed: -
rt: 1.28s
correct
------------------------------------
block 0, trial 19: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.66s
correct
------------------------------------
block 0, trial 20: stimulus=j, target=m
model raw: -
parsed: -
rt: 1.71s
incorrect
------------------------------------
block 0, trial 21: stimulus=z, target=-
model raw: -
parsed: -
rt: 1.68s
correct
------------------------------------
block 0, trial 22: stimulus=h, target=-
model raw: -
parsed: -
rt: 1.34s
correct
------------------------------------
block 0, trial 23: stimulus=j, target=m
model raw: m
parsed: m
rt: 1.53s
correct
------------------------------------
[AUTO-SAVED] all_trials_verbal_temp0.json

========== Running 3back_1 ==========
block 1, trial 0: stimulus=x, target=-
model raw: -
parsed: -
rt: 1.24s
correct
------------------------------------
block 1, trial 1: stimulus=k, target=-
model raw: -
parsed: -
rt: 1.35s
correct
------------------------------------
block 1, trial 2: stimulus=p, target=-
model raw: -
parsed: -
rt: 1.29s
correct
------------------------------------
block 1, trial 3: stimulus=c, target=-
model raw: -
parsed: -
rt: 1.62s
correct
------------------------------------
block 1, trial 4: stimulus=c, target=-
model raw: -
parsed: -
rt: 1.51s
correct
------------------------------------
block 1, trial 5: stimulus=r, target=-
model raw: -
parsed: -
rt: 1.41s
correct
------------------------------------
block 1, trial 6: stimulus=l, target=-
model raw: -
parsed: -
rt: 1.84s
correct
------------------------------------
block 1, trial 7: stimulus=d, target=-
model raw: -
parsed: -
rt: 1.72s
```

```
rt: 1.42s
correct
------------------------------------
block 1, trial 8: stimulus=r, target=m
model raw: -
parsed: -
rt: 1.47s
incorrect
------------------------------------
block 1, trial 9: stimulus=j, target=-
model raw: -
parsed: -
rt: 1.60s
correct
------------------------------------
block 1, trial 10: stimulus=d, target=m
model raw: -
parsed: -
rt: 1.53s
incorrect
------------------------------------
block 1, trial 11: stimulus=r, target=m
model raw: -
parsed: -
rt: 1.56s
incorrect
------------------------------------
block 1, trial 12: stimulus=y, target=-
model raw: -
parsed: -
rt: 1.85s
correct
------------------------------------
block 1, trial 13: stimulus=d, target=m
model raw: -
```

```
# ========================================================
# 12. Compare temp=1 vs temp=0
# ========================================================

def compare_two_temperatures(result_temp1, result_temp0, n_list):
        rows = []

        for n in n_list:
                acc_t1 = result_temp1["summary_stats"][n]["accuracy"]["mean"]
                acc_t0 = result_temp0["summary_stats"][n]["accuracy"]["mean"]
                dp_t1 = result_temp1["summary_stats"][n]["d_prime"]["mean"]
                dp_t0 = result_temp0["summary_stats"][n]["d_prime"]["mean"]

                rows.append([
                        f"{n}-back",
                        round(acc_t1, 2),
                        round(acc_t0, 2),
                        round(acc_t0 - acc_t1, 2),
                        round(dp_t1, 2),
                        round(dp_t0, 2)
                ])

        df_compare = pd.DataFrame(
                rows,
                columns=["N-back", "Temp=1 Accuracy", "Temp=0 Accuracy", "Accuracy Delta", "Temp=1 D′ ", "Temp=0 D′ "]
        )

        print(tabulate(df_compare.values, headers=df_compare.columns, tablefmt="github"))
        return df_compare

df_compare = compare_two_temperatures(result_temp1, result_temp0, N_LIST)
df_compare
```

```
| N-back   |   Temp=1 Accuracy |   Temp=0 Accuracy |   Accuracy Delta |   Temp=1 D′  |   Temp=0 D′  |
|----------|-------------------|-------------------|------------------|--------------|--------------|
| 1-back   |               100 |             95.83 |            -4.17 |         4.65 |         3.48 |
| 3-back   |                75 |             75    |             0    |         1.16 |         1.16 |
```

```
block 1, trial 19: stimulus=r, target=-
model raw: -
parsed: -
rt: 1.31s
correct
----
parsed: -
rt: 1.61s
incorrect
```

	N-back	Temp=1 Accuracy	Temp=0 Accuracy	Accuracy Delta	Temp=1 D′	Temp=0 D′
0	1-back	100.0	95.83	-4.17	4.65	3.48
1	3-back	75.0	75.00	0.00	1.16	1.16

```
# ========================================================
# 13. If you want to save the compare table as a CSV
```