Asymmetrical temporal distance memory precision in precentral gyrus

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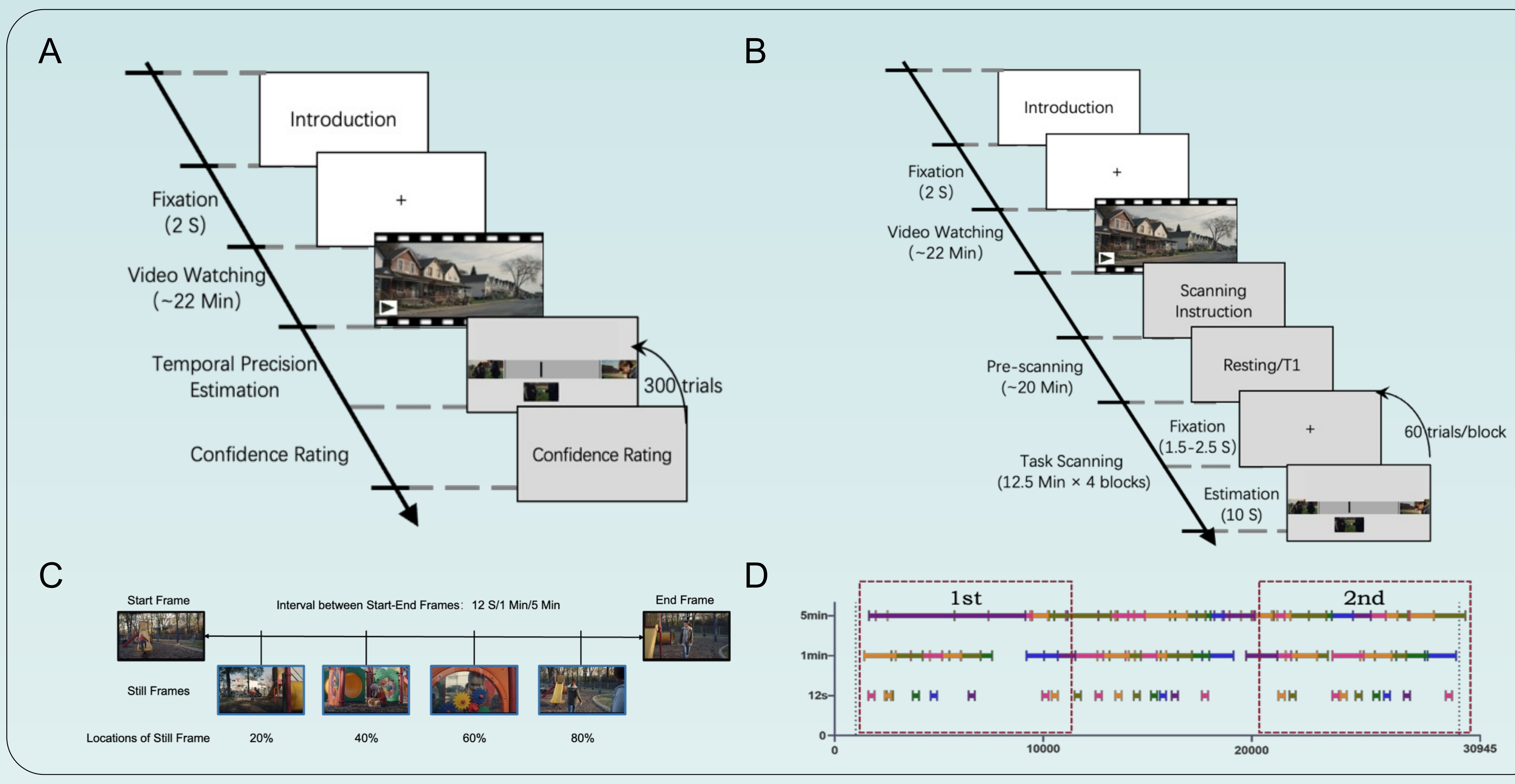
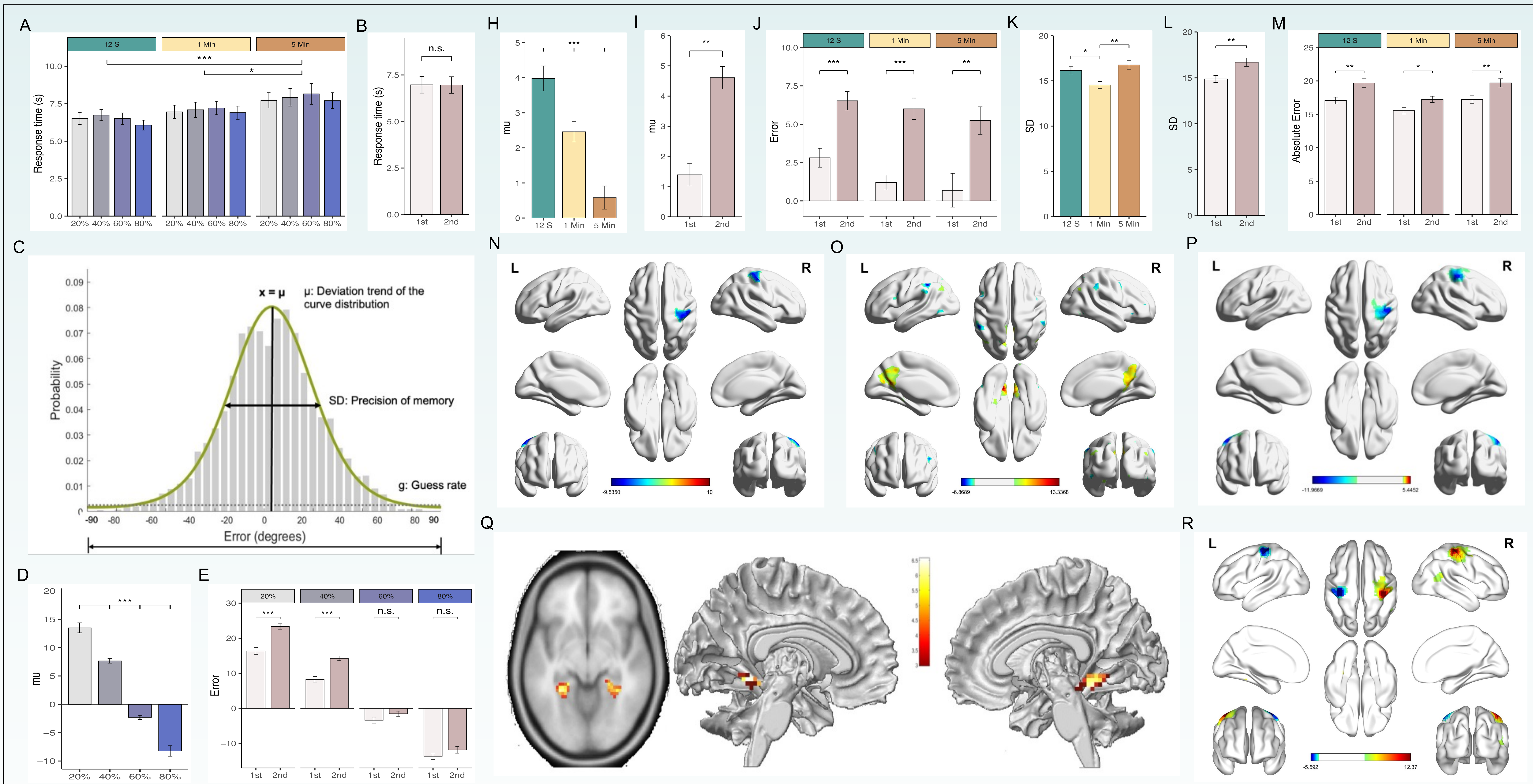
Introduction

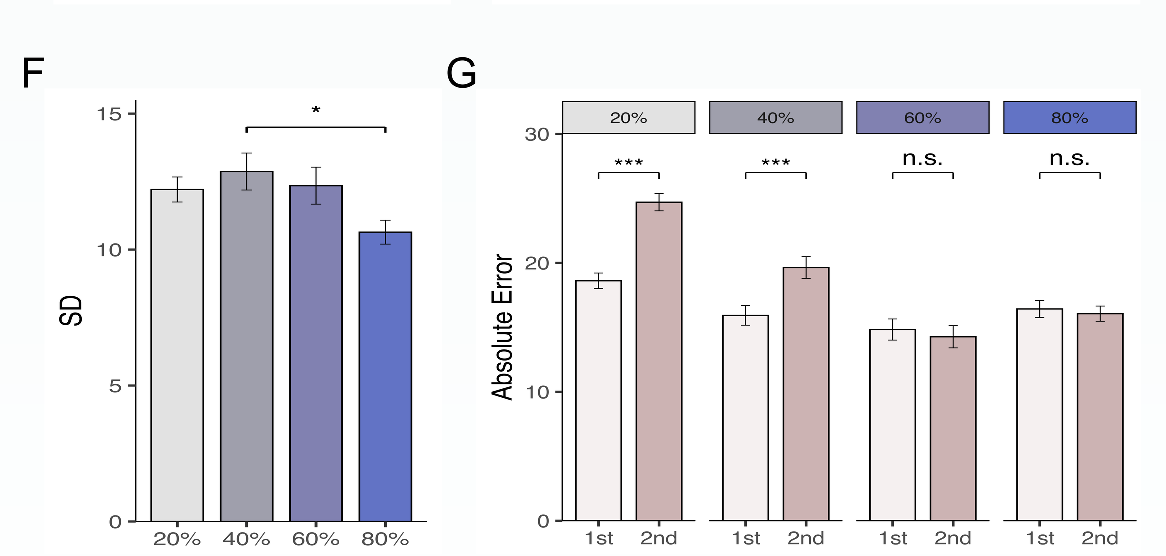
Episodic memory is characterized by its integration of temporal and spatial contexts, serving as the foundation for decision-making, planning, the (re)construction of past experiences, and future-oriented thinking (Tulving, 2002; Schacter et al., 2008). Three types of temporal information have been identified in episodic memory. Absolute time refers to the estimation of the time location of specific events (Pu et al., 2022) , while relative time includes the judgment of both the temporal order of events and the temporal distance between events (Wang et al., 2020; Fountas et al., 2020; Tsao et al., 2022), respectively. Accumulating empirical evidence has demonstrated the cognitive and neural mechanisms underlying the representation of time location (Pu et al., 2022) , temporal order judgement (Kwok et al., 2015) and temporal distance (Kuruvilla, M. V. et al., 2020) during episodic memory retrieval. However, the neural basis for the representation of temporal precision remains unknown. To address this question, in the present study, we conducted a behavioral study (n = 30) and a fMRI study (n = 20). After encoding a 22-minute video, participants took part in a temporal distance estimation task to drag a target frame to its correct temporal position between two reference frames. Manipulations included varying the temporal separation between reference frames (12-s/ 1-min/ 5-min intervals) and the target frame's position relative to the 1st reference frame (at 20%, 40%, 60%, or 80%). We utilized a Standard Mixture Model with Bias to produce two key indices related to memory precision: estimation precision (SD), precision bias (μ).

Methods



Results





Compared to shorter intervals, the results revealed that participants took more time to map the still frame to its target location after rescaling the longer intervals between two given frames (A), while the response time remained unaffected by the target locations (A) and segments (B). Figure C demonstrates the Standard Mixture Model with Bias to produce two key indices related to memory precision: estimation precision (SD), precision bias (μ). Memory precision (SD) was influenced by the target frame's proximity to the reference frames and its absolute location in the video, with greater precision observed for targets closer to either reference frame or positioned in the first half of the video. Notably, memory precision bias (μ) was more pronounced for targets closer to the 1st reference frame, indicating an exacerbated temporal memory precision bias linked to memory's historical context (D - M). Additionally, activation in the precentral gyrus correlated negatively with estimation error, while activation in the right precentral gyrus decreased with increasing memory precision bias (L). Compared to the 12-second interval, the angular gyrus and fusiform gyrus exhibited higher activation during temporal precision estimation in the 1-minute intervals, while portions of the angular gyrus, parietal lobe, and temporal lobe showed decreased activation (O). Activation of the right precentral gyrus progressively decreased as the location shifted from 20% to 80% (P). Increased activation of the lingual gyrus was observed when estimations were made for targets from the latter half of the video (Q). Significant decreases in activation were observed in the precentral gyrus and medial temporal gyrus when comparing pre- and post-locations (R).

Conclusion

Temporal distance estimation accuracy is influenced by the interval between the start and end frames in a video (timeline length), the relative position of the still image during recall (position of the still frame), and the location of the selected image during the trial (trial position in the video). Participants' estimations tended to shift toward the midpoint of the timeline. Parametric analysis revealed that as the error—the difference between the selected and actual positions of the still frame—increased linearly, activation in the precentral gyrus decreased. Additionally, when the still frame's position shifted from 20% to 80% of the timeline, activation in the right precentral gyrus also declined. Contrast analysis showed that, compared to a 12-second timeline, the 1-minute timeline led to increased activation in the angular gyrus and fusiform gyrus (1 minute > 12 seconds), while activation in parts of the angular gyrus, parietal lobe, and temporal lobe decreased (1 minute < 12 seconds). These findings underscore the precentral gyrus's role in temporal distance estimation and indexing memory precision bias concerning asymmetrical compressed time representation.

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