Stimulus properties and visual field location interact to drive performance-independent perceptual confidence

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Abstract

Perceptual confidence tracks decision accuracy, yet it is also systematically shaped by both stimulus properties and spatial location. Using a luminance comparison task, we assessed how multiple stimulus dimensions influence observers' relative brightness judgments and perceptual confidence. These dimensions included visual field location (eccentricity and polar angle) in Experiments 1 and 2, and additionally stimulus noise and overall stimulus strength in Experiment 1. We applied the recently developed *relative psychometric function* approach to characterize these dimensions' effects on confidence across a range of matched task accuracies, rather than at a single fixed performance level. Observers' confidence increased with both stimulus noise and visual eccentricity, even as performance range was matched across all conditions. These effects depended on stimulus strength – i.e., the overall luminance of the stimuli – revealing interactions among different sources of uncertainty in shaping metacognitive judgments. Together, these results extend previous accounts of the relationship between confidence and accuracy to reveal integration of multiple uncertainty sources and to include suprathreshold stimuli in brightness perception.

Precis

We studied the relationship between visual performance and confidence as a function of eccentricity, polar angle, overall stimulus luminance, and time-dependent variability in luminance. We found that these multiple sources of uncertainty interact to affect the accuracy-confidence relationship.

Keywords

visual field; luminance; uncertainty; visual metacognition; relative psychometric function

Introduction

Our experience of the visual world is often accompanied by a subjective sense of certainty, or *perceptual confidence*. While perceptual confidence typically covaries with decision variables such as task accuracy or reaction time (Baranski & Petrusic, 1994; Yeung & Summerfield, 2012), it is often thought to be a distinct process that reflects the probability that our visual judgment is veridical (reviews: Fleming, 2024; Mamassian, 2016; Miyoshi, Webb, Rahnev, & Lau, 2024; Rahnev, 2021, 2025). Perceptual confidence and task performance rely on at least partially physiologically dissociable regions (Lau & Passingham, 2006; Pereira et al., 2020; Peters, Fesi, et al., 2017; Rahnev, Maniscalco, Luber, Lau, & Lisanby, 2012; Rounis, Maniscalco, Rothwell, Passingham, & Lau, 2010; Samaha, Iemi, & Postle, 2017), may rely on distinct sources of perceptual evidence (Maniscalco et al., 2021; Maniscalco, Peters, & Lau, 2016; Zylberberg, Barttfeld, & Sigman, 2012), and have been proposed to arise from at least partially independent computational processes (Adler & Ma, 2018; Aitchison, Bang, Bahrami, & Latham, 2015; Boundy-Singer, Ziemba, & Goris, 2023; Cleeremans, Timmermans, & Pasquali, 2007; Fleming & Daw, 2017; Hangya, Sanders, & Kepecs, 2016; Hellmann, Zehetleitner, & Rausch, 2024; Jang, Wallsten, & Huber, 2012; Maniscalco & Lau, 2016; Pleskac & Busemeyer, 2010).

Many stimulus and task manipulations have been found to be useful for isolating processes driving perceptual confidence from those driving task performance so that their potentially unique computations and neural correlates may be characterized (see Peters, 2022; Rahnev, 2025, for thorough discussions). A common experimental approach is to titrate some stimulus dimension (e.g., luminance, contrast, noise, timing, or motion coherence parameters) or task condition (e.g., spatial attentional deployment) such that performance is matched between experimental conditions while allowing subjective judgments such as confidence ratings to vary (Morales, Odegaard, & Maniscalco, 2022). These approaches have yielded several consistent findings.

First, across conditions with matched discrimination performance (i.e., equated signal-to-noise ratio), increasing the total amount of sensory evidence available (*stimulus strength*) results in higher perceptual confidence (Ko et al., 2022; Koizumi, Maniscalco, & Lau, 2015; Odegaard, Grimaldi, et al., 2018; Samaha, Barrett, Sheldon, LaRocque, & Postle, 2016; Samaha & Denison, 2022; Samaha, Switzky, & Postle, 2019). Relatedly, many studies attribute increased confidence to the increase in the amount of evidence specifically supporting the selected stimulus identity in discrimination tasks (Maniscalco et al., 2021, 2016; Peters, Thesen, et al., 2017; Zylberberg et al., 2012). This latter finding has been called the *positive evidence bias*, interpreted as confidence reflecting reliance on the magnitude of perceptual decision-congruent evidence. Several models have been proposed to account for these findings. Confidence may reflect a confirmation bias if it depends on continued evidence accumulation after the perceptual choice (Maniscalco et al., 2021; Moran, Teodorescu, & Usher, 2015; Pleskac & Busemeyer, 2010). Alternatively, the confidence readout may be corrupted by multiplicative noise that follows a lognormal distribution and scales with the magnitude of the internal signal (Shekhar & Rahnev, 2021). In cases where confidence scales with stimulus strength for incorrect or unchosen responses, it may reflect either heightened sensitivity to evidence near a discrimination boundary (Boldt, Sun, & Desender, 2025), or dependence on a weighted combination of the task-relevant decision evidence and stimulus visibility evidence (Rausch, Hellmann, & Zehetleitner, 2018, 2021).

Second, the effect of the reliability of the stimulus (external, or informational noise) on perceptual confidence has been found to depend on the specific noise manipulation and the type of task used. For example, when judging the average orientation of a group of gratings, observers displayed greater overconfidence in the condition with high variability in individual gratings' orientations compared to the condition with low contrast gratings (Herce Castañón et al., 2019). In some paradigms, stimulus reliability interacts with stimulus strength: decreasing reliability (i.e., increasing noise) produces a larger increase in confidence at low relative to high stimulus strength (Zylberberg, Fetsch, & Shadlen, 2016), and can even reverse direction to decrease confidence when stimulus strength is high (Zylberberg, Roelfsema, & Sigman, 2014). In other paradigms, observers' overall perceptual confidence tracks performance well and decreases in conditions with lower stimulus reliability when signal-to-noise ratio is preserved or task difficulty is fixed (Boldt, de Gardelle, & Yeung, 2017; Desender, Boldt, & Yeung, 2018; Ko et al., 2022).

Third, a consistent and meaningful way in which task performance and perceptual confidence dissociate under uncertainty is in *subjective inflation*, also known as *peripheral inflation* when specific to increased uncertainty in the periphery compared to to the center of the visual field. Subjective inflation is a phenomenon in which confidence or visibility exceed what would be expected based solely on task performance in conditions with higher noise. Subjective inflation has been observed in the visual periphery relative to stimuli that are more foveal when performance was matched between the two locations (Odegaard, Chang, Lau, & Cheung, 2018; Rahnev et al., 2011; Rajananda, Peters, Lau, & Odegaard, 2017; Solovey, Graney, & Lau, 2015; Tian et al., 2025). The shared interpretation of these studies is that internal signal variability is higher for stimuli presented in the visual periphery – similar to several of the noise manipulations described above – lending to the appearance of a liberal detection bias when observers employ a fixed criterion across low and high noise conditions under a signal detection framework. However, these studies observed subjective inflation within a limited visual eccentricity (<12 degrees of visual angle; dva) and with low-level visual stimuli that are confined to a small area of the visual field. At greater eccentricities, observers exhibit no inflation or even underconfidence with low-level visual stimuli (Pruitt, Knotts, & Odegaard, 2024; Toscani, Mamassian, & Valsecchi, 2021) and overconfidence in the periphery with scene perception (Okubo, Miyoshi, Yokosawa, & Nishida, 2026; Okubo & Yokosawa, 2023) and scene categorization (Sharvashidze, Toscani, & Valsecchi, 2025) where the scene occupies a larger spatial extent. These findings suggest the presence of subjective inflation may interact with engagement of global vs. local processing, or with the use of threshold vs. suprathreshold stimuli.

To date no study has characterized the relationship between objective and subjective perceptual decisions around the entire visual field, which displays systemic asymmetry. For most visual tasks, performance declines with eccentricity (for a review, see Strasburger, Rentschler, & Jüttner, 2011) and varies as a function of polar angle. At a fixed eccentricity beyond the parafovea, task accuracy and speed is typically better on the horizontal compared to the vertical meridian (horizontal-vertical anistropy, HVA) and on the lower compared to the upper vertical meridian (vertical meridian asymmetry, VMA), and intermediate at oblique angles. Such differences are called *polar angle asymmetries* (sometimes called *performance fields*; Altpeter, Mackeben, & Trauzettel-Klosinski, 2000; Mackeben, 1999) and are reflected in the anatomical and physiological organization of the brain, from the retina to – and possibly beyond – the visual cortex (for a review, see Himmelberg, Winawer, & Carrasco, 2023). It is worth asking then whether the relationship between perceptual performance and confidence is also systemically non-uniform across the visual field, such that the degree of subjective inflation would depend on precise visual field location. In other words, do observers subjectively perceive polar angle asymmetry?

Here, we incorporate these empirical findings into an omnibus study that comprehensively assesses the influence and interaction of visual field location, stimulus strength, stimulus reliability, and task difficulty on the relationship between task accuracy and perceptual confidence. We adapted the 2-alternative forced choice luminance comparison task design from (Ko et al., 2022), which used dynamic, flickering stimuli that allow for the manipulation of the physical noise of the stimulus, such that high variability in luminance flicker corresponded to low stimulus reliability, and vice versa. We compared two levels of stimulus strength (the summed, overall luminance of the stimuli) to observe the effect of increased overall luminance on performance-relative confidence. To assess the interaction of these factors with visual eccentricity, we added visual field locations to this paradigm, such that the luminance comparisons were made between isoeccentric stimuli in the parafovea (2 dva) or periphery (8 dva), at horizontal and vertical polar angle locations (Experiment 1) or at intercardinal polar angle locations (Experiment 2). We employed these manipulations across seven levels of task difficulty, controlled by the real difference in mean luminance between the two stimuli compared on each trial.

Crucially, previous studies that have measured perceptual confidence while "matching" task performance typically do so at one or few performance levels. The variation in confidence reports at a given matched performance level could thus depend on the absolute level of performance chosen (Morales et al., 2022). This is apparent in studies that have documented interaction effects between metacognitive reports and task condition that depended on the absolute level of the stimulus (Rahnev et al., 2011; Zylberberg et al., 2014). To address this potential limitation, we compared confidence for a matched range of performance across all conditions using the *relative psychometric function* analytic approach (Maniscalco et al., 2026).

To summarize, perceptual confidence can systematically dissociate from objective task performance under uncertainty, but the form of this dissociation depends on both stimulus properties and task context. In particular, differences in visual field location, stimulus strength, and stimulus reliability may each alter internal signal variability in ways that affect confidence beyond what is predicted by performance alone and in ways that might vary as a function of polar angle and eccentricity. To isolate these effects, we measured confidence across a matched range of task performance while independently manipulating visual field location and stimulus properties, allowing us to assess how subjective confidence varies across the entire visual field when objective performance is held constant.

Experiment 1

Methods

Observers

Eight observers (5 female, mean age: 25) participated in Experiment 1. All observers had normal or corrected-to-normal vision and were naive to the purposes of the study. All observers provided informed written consent under a protocol approved by the University of California Irvine Institutional Review Board. Observers were paid $15/hour, with a $20 completion bonus at the end of the study.

Apparatus

Experiment 1 and Experiment 2 had the same apparatus. We generated stimuli on a Dell Inspiron 5680 PC computer running Windows 10. Stimuli were displayed on a cathode ray tube (CRT) monitor (NEC MultiSync FE2111SB; 1280 x 1024) using a VPixx DATAPixx to precisely control stimulus presentation timing. We gamma-corrected the monitor using a Konica Minolta LS-100 Luminance Meter (Tokyo, Japan) with 8-bit accuracy. Observers sat in a dark and sound-attenuated room and viewed the display at a distance of 75 cm, with their head position stabilized by a chin rest. Binocular eye position was monitored using an infrared eye tracker (LiveTrack Lightning, Cambridge Research Systems, Rochester, Kent, United Kingdom) at 500 Hz to ensure fixation.

Stimuli and procedure

In this two-alternative forced-choice luminance comparison task, observers indicated which of two dynamic "flickering" circular patches was brighter on average. These patches were presented equidistant from central fixation, either on the horizontal meridian, one to the left and one to the right of central fixation, or along the vertical meridian, one above and one below fixation. The location meridian (vertical or horizontal) was randomized between blocks and consistent within each block. We incorporated a 7 (relative luminance difference) × 2 (stimulus noise) × 2 (overall luminance value) × 2 (location meridian) × 2 (eccentricity) within-subjects design. Stimuli conditions except for the location meridian were randomized on each trial. We used the method of constant stimuli across stimulus values, which did not differ overall between subjects except by their pseudorandom order of presentation. There were 64 trials per stimulus combination, totaling 7168 trials across all the stimulus conditions. This translated to 8 blocks of 112 trials per experimental session, totaling 8 sessions and roughly 8 experimental hours for each observer.

To compare performance between the periphery and the parafovea, we presented the stimuli either at 8 dva or 2 dva, respectively. These eccentricities were chosen because polar angle asymmetries typically emerge beyond ~2 dva, and to avoid ceiling performance in the center of the visual field corresponding to the fovea. Each of the two circular patches subtended 2 dva and changed in luminance with every frame refresh (every 13.3ms at 75 Hz). On each refresh, the luminance value for each patch was determined by randomly drawing values sampled from a Gaussian distribution. On each trial, the means of the two independent Gaussian distributions were set by RGB value triplets, such that one mean was always higher than the other. The two distributions had means that were both 'high' (high overall luminance; one patch was 137 and the other was 137 + the relative luminance difference) or both 'low' (low overall luminance; one patch was 77 and the other was 77 + the relative luminance difference). Their difference could be one of seven values, [5, 12, 19, 26, 33, 40, 47], with smaller values lending to higher task difficulty and lower discriminability between the patches. On any one trial, the two normal distributions had the same standard deviation which was either 'high' (high stimulus noise condition, 51) or 'low' (low stimulus noise condition, 25.5). Generating distributions were truncated such that if the sampled value on any refresh was less than 0 or greater than 255, the value was resampled. The positions of the stimuli were counterbalanced such that the brighter patch appeared equally at left and right locations, and equally at upper or lower locations.

All stimuli were presented on a black display background. Observers were instructed to maintain their gaze on a white circle with radius 0.3 dva at the center of the screen throughout stimulus presentation. If there was an eye blink or the eyes deviated >1.5 dva from fixation during the time the circular patch stimuli were on the screen, the trial immediately aborted and was repeated at the end of the block. Each trial was initiated by fixation for 400 ms. After a short 200 ms delay, the patch stimuli onset, and observers indicated which patch they perceived to be brighter on average with a keyboard button press. The stimuli offset at the time of decision. If, after 1500 ms, observers had not made a response, the trial was aborted and repeated at the end of the block. Following the perceptual brightness decision, observers reported their subjective confidence that they had chosen correctly on a numerical scale, where 1 corresponded to "not confident," 2 to "somewhat not confident," 3 to "somewhat confident," and 4 to "very confident." Confidence ratings were not required on trials in which the relative brightness decision was not made. For all other trials, if no confidence rating was reported after 1500 ms, the trial was aborted and repeated at the end of the block. After the observer reported their confidence level, there was a 250 ms intertrial interval, and the next trial began. No feedback was given in this task.

Before the main experimental sessions, observers completed three practice blocks of ten trials per block to familiarize themselves with the task procedure. The first practice block was slowed down and easy: observers had 3000 ms to report both the luminance comparison decision and the confidence rating, and the circular patches had values that were drawn from Gaussian distributions that had a large difference in their mean (50 and 200) and low standard deviation (15) relative to the values used in the main task. The second practice block was easy like the first practice block but employed the same faster timing as the main task, with 1500 ms to report the perceptual brightness decision and the confidence rating. The third practice block employed the same timing and stimulus parameters as the main task.

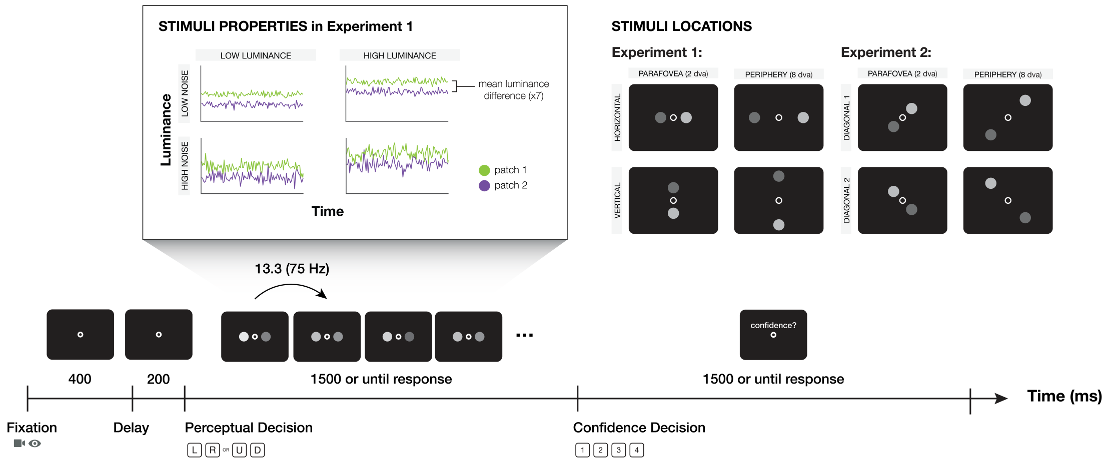

Figure 1

Stimuli & trial sequence. *On each trial, two flickering circular patches appeared equidistant from center fixation at 2 dva or at 8 dva. Patch stimuli appeared in the horizontal and vertical meridians in Experiment 1, and diagonal meridians in Experiment 2. Meridian varied pseudorandomly between blocks of trials but were the same within blocks. Eccentricity varied pseudorandomly between trials. Each patch changed luminance at 75 Hz. The patches' luminance values were drawn from two independent truncated Gaussian distributions. Using a keyboard, observers were asked to indicate which patch was brighter on average, and then subsequently asked to indicate their confidence that they had responded correctly on a 4-point scale.* ***Inset:*** *Stimulus properties in Experiment 1. The overall mean luminance values (both high or both low) and the standard deviations (stimulus noise; both high or both low) of these two Gaussian distributions varied across trials but were the same within a trial. In Experiment 1, all four combinations of noise and luminance were included; in Experiment 2, only the low-noise, low-luminance condition was included. The distance between their mean values (relative luminance difference) could take one of seven values in a trial.*

Analysis

MEASURES We collected the following measures for each condition, trial by trial: choice correctness, reaction time (RT), confidence judgment (1-4). We then computed, by condition, the performance (choice accuracy, probability of making a correct response) and the mean confidence judgment. Reaction time (RT) was log-transformed and then z-scored within each participant prior to statistical analysis. Two RT measures were used: mean zlog(RT) for luminance comparison decisions and mean zlog(RT) for confidence responses.

RELATIVE PSYCHOMETRIC FUNCTION ANALYSIS To quantify the relationship between objective performance and subjective confidence while controlling for differences in task accuracy across conditions, we employed the metaperceptual relative psychometric function (RPF) framework described by Maniscalco and colleagues (Maniscalco et al., 2026). The metaperceptual RPF relates objective performance to subjective confidence across an interval of performance levels matched across experimental conditions. This method is advantageous because performance and confidence tend to covary, and therefore evaluating their relationship necessitates an analytical framework that can differentiate effects of experimental manipulations on confidence from those on performance.

Conceptually, the RPF is derived by combining two functions estimated from the data: (1) a psychometric function relating stimulus level to performance (choice accuracy), and (2) a function relating stimulus level to confidence. By eliminating stimulus level (relative luminance difference) as an explicit variable and expressing confidence directly as a function of performance, the RPF provides a principled way to compare confidence across experimental conditions at matched levels of objective accuracy. This approach is particularly important in tasks where performance and confidence covary, as it avoids confounding changes in confidence with shifts in objective sensitivity.

In the present study, adequate parametric psychometric function fits could not be obtained for all observers in all conditions. To mediate, we employed the non-parametric approach described by Maniscalco and colleagues (Maniscalco et al., 2026). Specifically, for each observer and condition, we linearly interpolated performance as a function of stimulus level and confidence as a function of stimulus level across the discrete stimulus values tested. The RPF was then obtained by mapping interpolated confidence values onto interpolated performance values, yielding a piecewise linear estimate of confidence as a function of performance.

To summarize the RPF, we computed two complementary scalar measures (Maniscalco et al., 2026). First, we calculated the relative area under the RPF curve (rAUC), defined as the area under the confidence–performance curve across a fixed interval of performance levels that was common to all conditions, relative to the maximal area under the curve that could occur for that interval. This interval was bounded by the highest minimum performance level and the lowest maximum performance level observed across conditions, ensuring that comparisons were restricted to a shared performance range. Second, we computed the normalized average confidence over this same performance interval, denoted ($\bar{P}_2$), which represents the mean confidence normalized by the width of the performance interval. Because performance ranges can differ across observers, ($\bar{P}_2$) provides a normalized summary of performance-matched confidence that is less sensitive to individual differences in psychometric slope or dynamic range.

Importantly, the interpolation-based RPF does not assume a specific parametric form for either the performance or confidence psychometric functions, making it well suited for conditions in which stimulus manipulations induce non-linear or observer-specific response patterns. This non-parametric interpolation approach has also been previously demonstrated to not produce systematic biases in estimation of the effects of interest - i.e., the systematic, quantitative relationship between performance and confidence (Maniscalco et al., 2026). (We note that, had we been able to fit all the data using psychometric functions, we might expect larger effect sizes than those reported below.)

STATISTICAL ANALYSIS For the relationship between accuracy and confidence resulting from the RPF analysis, all statistical analyses were also conducted in a repeated measures analysis of variance (rmANOVA) framework, using the two summary measures (rAUC, $\bar{P}_2$) calculated for each observer and each experimental condition as described above. To assess the effects of visual field location and stimulus manipulations on the quantitative relationship between performance and confidence, we performed separate 4-way rmANOVAs on rAUC and on $\bar{P}_2$. Each rmANOVA included the within-subject factors location meridian (horizontal vs. vertical), eccentricity (2 vs. 8 dva), stimulus noise (low vs. high), and overall luminance (low vs. high). Significant interactions were followed up by paired-sample t-tests to characterize the direction and significance of effects. All post-hoc comparisons were corrected for multiple comparisons using the Holm-Bonferroni procedure. Where appropriate, effect sizes are reported as partial eta squared (η_p^2) for rmANOVA effects and as mean differences with standard error and Cohen's *d* for pairwise comparisons.

Results

Accuracy, confidence, & their relationship

As expected, both accuracy (**Figure 2a**) and confidence (**Figure 2b**) increased as a function of relative luminance difference across all conditions and visual field locations.

The interval of choice accuracy levels shared among all conditions was between 0.6348 and 0.7754, shown in **Figure 2c**. In this interval, we calculated both rAUC **Figure 2d** and $\bar{P}_2$ **Figure 2e** for each condition.

For both rAUC and $\bar{P}_2$, we observed a significant main effect of stimulus noise (rAUC: $F(1,7) = 8.906$, $p = 0.020$, $\eta_p^2 = 0.560$; $\bar{P}_2$: $F(1,7) = 10.543$, $p = 0.014$, $\eta_p^2 = 0.601$), with higher noise resulting in higher rAUC ($t(7) = 2.984$, $p = 0.020$, Mean Difference = 0.010, $SE = 0.003$, Cohen's $d = 0.077$) and $\bar{P}_2$ ($t(7) = 3.247$, $p = 0.014$, Mean Difference = 0.143, $SE = 0.044$, Cohen's $d = 0.450$). For $\bar{P}_2$ only, a main effect of overall luminance ($F(1,7) = 5.922$, $p = 0.045$, $\eta_p^2 = 0.458$) was significant, with higher luminance resulting in higher $\bar{P}_2$ ($t = 2.434$, $p = 0.045$, Mean Difference = 0.240, $SE = 0.099$, Cohen's $d = 0.759$). This effect was marginally significant for rAUC ($p = 0.069$).

We also observed a significant 2-way interaction between stimulus noise and overall luminance (rAUC: $F(1,7) = 6.499$, $p = 0.038$, $\eta_p^2 = 0.481$; $\bar{P}_2$: $F(1,7) = 8.003$, $p = 0.025$, $\eta_p^2 = 0.533$). This interaction was driven by stimulus noise, with lower rAUC and $\bar{P}_2$ in the low noise, low luminance condition compared to the high noise, low luminance condition (rAUC: $t(7) = -3.925$, $p = 0.009$, Mean Difference = -0.018, $SE = 0.005$, Cohen's $d = -0.134$; $\bar{P}_2$: $t(7) = -4.304$, $p = 0.004$, Mean Difference = -0.259, $SE = 0.060$, Cohen's $d = -0.816$) and to the high noise, high luminance condition (rAUC: $t(7) = -3.199$, $p = 0.048$, Mean Difference = -0.026, $SE = 0.008$, Cohen's $d = -0.196$; $\bar{P}_2$: $t(7) = -3.543$, $p = 0.028$, Mean Difference = -0.383, $SE = 0.108$, Cohen's $d = -1.209$). Additionally, for $\bar{P}_2$, the low noise, low luminance condition was significantly lower than in the low noise, high luminance condition ($t(7) = -3.332$, $p = 0.033$, Mean Difference = -0.356, $SE = 0.107$, Cohen's $d = -1.125$). This comparison was only marginally significant for rAUC ($p = 0.064$).

For $\bar{P}_2$ only, we observed a significant 2-way interaction between eccentricity and overall luminance ($F(1,7) = 7.166$, $p = 0.032$, $\eta_p^2 = 0.506$); however, post-hoc comparisons revealed no significant effects. The interaction between eccentricity and stimulus noise was marginally significant for both rAUC and $\bar{P}_2$ (rAUC: $p = 0.091$; $\bar{P}_2$: $p = 0.056$). Follow-up t-tests indicated that both measures were significantly higher at 2 dva in the high noise condition compared to the low noise condition (rAUC: $t(7) = 3.561$, $p = 0.027$, Mean Difference = 0.014, $SE = 0.004$, Cohen's $d = 0.105$; $\bar{P}_2$: $t(7) = 3.961$, $p = 0.012$, Mean Difference = 0.204, $SE = 0.052$, Cohen's $d = 0.644$). These results suggest that stimulus properties could have differing effects on the relationship between performance and subjective confidence depending on where the stimulus appeared.

There was also a 3-way interaction among location meridian, eccentricity, and overall luminance (rAUC: $F(1,7) = 9.614$, $p = 0.017$, $\eta_p^2 = 0.579$; $\bar{P}_2$: $F(1,7) = 5.941$, $p = 0.045$, $\eta_p^2 = 0.459$). However, post-hoc comparisons revealed no significant pairings for either rAUC or $\bar{P}_2$. Finally, we observed a significant interaction among all factors, meridian × eccentricity × noise × overall luminance (rAUC: $F(1,7) = 6.194$, $p = 0.042$, $\eta_p^2 = 0.469$; $\bar{P}_2$: $F(1,7) = 9.740$, $p = 0.017$, $\eta_p^2 = 0.582$).

All post-hoc t-test p-values were corrected using Holm-Bonferroni. All other effects and interactions did not reach significance ($p > 0.05$). Full statistical reports can be found in the Appendix.

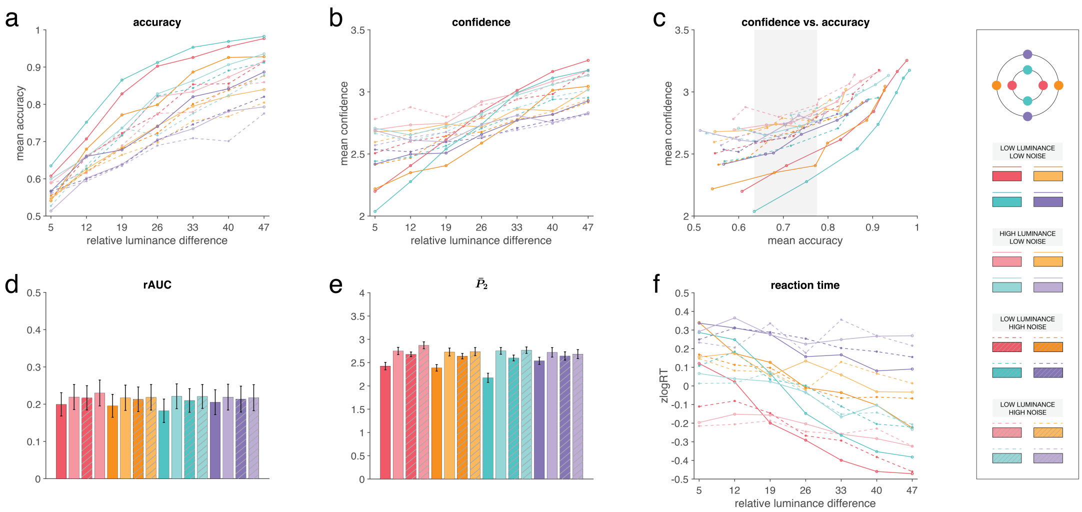

Figure 2

Experiment 1 results. *The horizontal meridian at 2 dva (parafovea) and 8 dva (periphery) is represented in pink and orange, respectively. The vertical meridian at 2 dva and 8 dva is represented in blue and purple, respectively.* ***a.*** *Mean accuracy (i.e., probability of making a correct response) at each level of relative luminance difference.* ***b.*** *Mean confidence rating at each level of relative luminance difference.* ***c.*** *Mean confidence across mean accuracy. The shaded region represents the range of performance that was shared across all conditions. From this shaded region, rAUC (**d.**) and $\bar{P}_2$ (**e.**) were computed, with error bars denoting ±1 SEM.* ***f.*** *Mean reaction time in zlog units at each level of relative luminance difference. In **a, b, c, and f**, low stimulus noise is indicated by solid lines, and high stimulus noise is indicated by dashed lines. In **c and d**, solid bars represent low stimulus noise and hatched bars represent high stimulus noise. In all panels, darker colors represent low overall luminance, and lighter colors represent high overall luminance. In **a, b, c, and f**, SEM was omitted for clarity.*

Within each stimulus property condition

Given that we found differences between the low noise and low luminance condition and the other stimulus noise × overall luminance conditions, we decided to further explore by asking whether there were meaningful differences within each stimulus noise × overall luminance condition. We did so by conducting separate 2-way rmANOVAs within the low noise and low luminance condition, the low noise and high luminance condition, the high noise and low luminance condition, and the high noise and high luminance condition.

In the low stimulus noise × low overall luminance condiiton, we observed an interaction between eccentricity and location meridian for $\bar{P}_2$ ($F(1,7) = 5.7038$, $p = 4.4916$, $\eta^2_p = 0.449$). Post-hoc t-tests revealed no significant comparisons, although the comparison between the vertical meridian at 2 dva and at 8 dva was marginally significant ($p = 0.070$). This interaction was marginally significant for rAUC ($p = 0.072$). This suggests that, for a fixed interval of accuracy, confidence was trending towards being higher in the vertical periphery compared to the vertical center. The same trends were not found for the horizontal meridian. In other words, it's possible that subjective inflation could be observed in the periphery, which could depend on the polar angle of the stimuli.

We did not observe meaningful differences in either rAUC or $\bar{P}_2$ in the other stimulus property conditions (see also the Appendix for statistical reports). These findings motivated Experiment 2, where we probed the effects of visual field location (meridian and eccentricity) at oblique polar angles while holding stimulus noise and overall luminance fixed at the low levels used in Experiment 1.

Reaction time

We performed two 4-way rmANOVAs on zlog(RT) for both luminance comparison decisions and confidence responses, with factors location meridian (horizontal or vertical), eccentricity (2 or 8 dva), stimulus noise (low or high), and overall luminance (low or high). For luminance comparison zlog(RT) (**Figure 2f**), we observed a significant main effect of eccentricity ($F(1,7) = 12.342$, $p = 0.01$, $\eta^2_p = 0.638$). Post hoc comparisons revealed significantly faster reaction times at 2 dva eccentricity in the parafovea compared to at 8 dva in the periphery (in zlog units: $t(7) = -3.513$, $p = 0.01$, Mean difference = -0.295, $SE = 0.084$, Cohen's $d = -1.412$). There were trending interactions between location meridian and noise ($F(1,7) = 4.131$, $p = 0.082$), and among location meridian, stimulus noise, and overall luminance ($F(1,7) = 4.094$, $p = 0.083$). All other effects and interactions did not reach significance ($p > 0.05$).

For the confidence decision zlog(RT), there was an interaction between location meridian and eccentricity ($F(1,7) = 6.124$, $p = 0.043$, $\eta^2_p = 0.467$). Post hoc comparisons revealed that this interaction was due to a significant faster reaction times between the vertical meridian at 2 dva and vertical meridian at 8 dva (in zlog units: $t = -3.223$, $p = 0.038$, Mean difference = -0.026, $SE = 0.008$, Cohen's $d = -0.452$). However, given that in this task confidence was reported after the perceptual decision, the reaction time for confidence is not likely to be a meaningful measure.

Experiment 2

Methods

Observers

Seventeen observers (9 females, mean age: 19.65) participated in Experiment 2. All observers had normal or corrected-to-normal vision and were naive to the purposes of the study. All observers provided informed written consent under a protocol approved by the University of California Irvine Institutional Review Board. All observers were naive to the purpose of the study and were paid $15/hour.

Stimuli and procedure

Experiment 2 has the same experimental design as Experiment 1, with the following exceptions:

1. The patch stimuli were presented at oblique polar angle locations, equidistant from the horizontal and vertical meridians. The goal of Experiment 2 was to evaluate the relationship between confidence and task accuracy at the oblique locations which have been found in previous studies to have comparable task accuracy. In each pseudorandomized block of trials, they appeared along one of the diagonal meridians: either in the upper left (135°) and lower right (315°), or in the upper right (45°) and lower left (225°), relative to central fixation. Stimulus eccentricity was the same as in Experiment 1, at 2 dva or at 8 dva.

2. Experiment 2 included only the low overall luminance condition (mean luminance of the dimmer patch = 77) and low luminance standard deviation (25.5; low stimulus noise) from Experiment 1. These stimulus properties were selected because they produced the largest effects in Experiment 1 and allowed for a reduction in trial count. This resulted in a 7 (difference in mean luminance) × 2 (location meridian) × 2 (eccentricity) within-subject design. There were 64 trials per stimulus combination, totaling 1792 trials across all conditions. Each observer completed 8 blocks of 112 trials per session across 2 sessions (approximately 2 hours total).

Statistical analyses

All analyses proceeded as with Experiment 1, with the exception that, because Experiment 2 included only a single stimulus noise and overall luminance condition, statistical analyses were limited to the within-subject factors location meridian and eccentricity. As in Experiment 1, the relationship between performance and confidence was quantified using rAUC and the normalized average confidence over the performance interval ($\bar{P}_2$). We performed separate rmANOVAs on these measures, and on mean z-scored log reaction time.

Results

RPF, rAUC, and $\bar{P}_2$

We calculated RPF rAUC **(Figure 3d)** and RPF $\bar{P}_2$ **(Figure 3e)** for each condition in the shared performance interval among all conditions (0.6360 to 0.8897), shown in **Figure 3c**. Two-way rmANOVAs on these measures with factors location meridian and eccentricity revealed a main effect of eccentricity (rAUC: $F(1,16) = 4.84$, $p = 0.043$, $\eta^2_p = 0.232$; $\bar{P}_2$: $F(1,16) = 5.526$, $p = 0.032$, $\eta^2_p = 0.257$). Post-hoc comparisons showed that rAUC and $\bar{P}_2$ were significantly lower at 2 dva than at 8 dva (rAUC: $t(16) = -2.200$, $p = 0.043$, Mean Difference = -0.028, $SE = 0.013$, Cohen's $d = -0.234$; $\bar{P}_2$: $t(16) = -2.351$, $p = 0.032$, Mean Difference = -0.123, $SE = 0.053$, Cohen's $d = -0.282$), indicating that confidence was higher in the visual periphery than in the parafovea for the matched range of accuracy.

Location meridian and the interaction between eccentricity and location meridian were not significant, ($p > 0.05$) (see also Appendix).

Reaction time

We performed 2-way rmANOVAs on mean zlog(RT) for both luminance comparison decisions and confidence responses, with factors location meridian and eccentricity **(Figure 3f)**. For the luminance comparison decision, we observed a significant main effect of eccentricity ($F(1,16) = 24.829$, $p < 0.001$, $\eta^2_p = 0.608$). Reaction times were significantly faster for stimuli in the parafovea at 2 dva compared to in the periphery at 8 dva, (in zlog units: $t(16) = -4.983$, $p < 0.001$, Mean difference = -0.191, $SE = 0.038$, Cohen's $d = -1.567$). Reaction time difference between location meridians and the interaction between location meridian and eccentricity were not significant ($p > 0.05$).

The rmANOVA for zlog(RT) for the confidence responses revealed no significant effects or interactions. As in Experiment 1, reaction time for confidence is not likely to be a meaningful measure in this task paradigm.

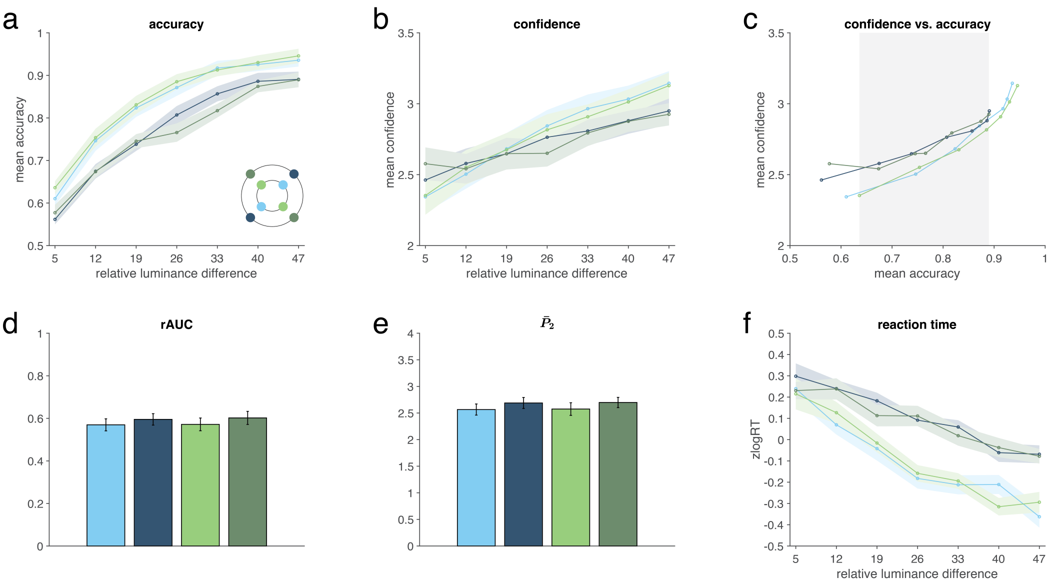

Figure 3

Experiment 2 results. *The diagonal meridian that includes the lower left and upper right is represented in blue. The diagonal meridian that includes the upper left and lower right is represented in green. Lighter colors represent the parafovea at 2 dva. Darker colors represent the periphery at 8 dva.* ***a.*** *Mean accuracy (probability of making a correct response) at each level of relative luminance difference.* ***b.*** *Mean confidence rating at each level of relative luminance difference.* ***c.*** *Mean confidence across mean accuracy. The shaded region represents the range of accuracy that was shared for all four eccentricity × meridian conditions. From this shaded region, rAUC (****d.****) and $\bar{P}_2$ (****e.****) was computed, with error bars representing ±1 SEM.* ***f.*** *Reaction time in zlog units at each level of relative luminance difference. In* ***a, b, and f****, shaded regions represent SEM.*

Discussion

Visual perception is shaped by multiple sources of uncertainty, including variability in the sensory signal itself, changes in stimulus strength, and differences in how information is encoded across the visual field. While perceptual performance is known to depend on these factors, it remains less clear how they jointly influence subjective confidence *independent of performance changes* – that is, when performance is controlled for or held constant. Here, we interrogated the concurrent and interacting effects of three types of noise – stimulus reliability, overall stimulus luminance, and visual field location – on the relationship between confidence and accuracy. Across two experiments, we assessed confidence under matched ranges of perceptual performance, allowing us to isolate systematic dissociations between subjective confidence and objective task accuracy.

In both experiments, we observed systematic dissociations between subjective confidence and objective task accuracy that depended on stimulus noise, stimulus luminance, and stimulus location. In Experiment 1, increasing stimulus reliability by reducing the physical variability of stimuli luminance decreased confidence for a matched range of task accuracy. This effect interacted with overall luminance: confidence was lowest in the high reliability (low noise) and low-luminance condition, whereas the other reliability-luminance combinations produced statistically equivalent performance-matched confidence levels (though marginally different for the high reliability and low overall luminance condition for rAUC). This pattern is consistent with previous findings showing that the effect of stimulus reliability on confidence depends on the strength of the stimulus (Zylberberg et al., 2016, 2014).

Across both Experiments 1 and 2, observers responded faster in the parafovea (2 dva) than in the periphery (8 dva), despite matched accuracy range across locations. This pattern contrasts with prior findings suggesting that processing in the periphery can be faster, albeit at the cost of reduced accuracy (Carrasco, McElree, Denisova, & Giordano, 2003; Jovanovic & Mamassian, 2019; Upadhyayula, Phillips, & Flombaum, 2023). Our results instead suggest that explicitly matching accuracy across eccentricities does not simply equate processing speed, but confers a speed advantage to the less peripheral location. Given evidence that confidence tends to increase as reaction time decreases (Baranski & Petrusic, 1994; Fetsch, Kiani, Newsome, & Shadlen, 2014; Kiani, Corthell, & Shadlen, 2014), these findings raise an intriguing possibility: confidence may be differentially influenced by the speed–accuracy tradeoff across the visual field. Specifically, central vision may benefit from higher accuracy at the cost of longer reaction times, whereas peripheral vision may benefit from faster responses but reduced accuracy. Future work that explicitly matches speed–accuracy tradeoffs across eccentricities would help clarify how confidence is constructed across the visual field.

Experiment 1 also revealed a reliable effect of overall luminance on confidence: observers reported higher confidence when both stimuli were brighter, even though task accuracy was matched across conditions. This finding is consistent with prior work showing that perceptual confidence increases with stimulus strength rather than solely reflecting the balance of evidence between competing alternatives (Ko et al., 2022; Koizumi et al., 2015; Miyoshi & Lau, 2020; Odegaard, Grimaldi, et al., 2018; Peters, Thesen, et al., 2017; Rausch et al., 2018; Samaha et al., 2016; Samaha & Denison, 2022; Zylberberg et al., 2012). Critically, this effect was observed across multiple levels of stimulus noise and across visual field locations, indicating that confidence covaried with stimulus strength even when signal-to-noise ratio was equated. These findings suggest that the effect of luminance on confidence – and perhaps the related effect of the positive evidence bias – may generalize across the visual field, and future studies could test this hypothesis.

In Experiment 2, we extended these findings by directly examining the effects of visual eccentricity while avoiding horizontal versus vertical meridian performance asymmetries, observing that confidence was higher for peripheral stimuli than for parafoveal stimuli at matched performance ranges, as reflected in both rAUC and $\bar{P}_2$. Importantly, performance-matched confidence did not differ between the two oblique meridians tested, supporting accounts of polar angle asymmetry that show similar performance for stimuli placed along oblique angles (Barbot, Xue, & Carrasco, 2021; Carrasco, Talgar, & Cameron, 2001; Himmelberg et al., 2023).

A key methodological feature of the present work – and a key component of our resulting empirical contribution – is the use of performance matching across a continuous range of accuracy, rather than equating performance at a single operating point, or pair of points, as is typically done. We quantified confidence–performance relationships using summary measures derived from the relative psychometric function (Maniscalco et al., 2026), allowing confidence to be compared across conditions that spanned comparable performance intervals. This approach mitigates concerns associated with ceiling or floor effects that can arise when confidence is assessed at isolated accuracy levels, particularly in suprathreshold tasks. Specifically, with the exception of few studies (Tian et al., 2025), subjective inflation has only been demonstrated near threshold detection or discrimination (Li, Lau, & Odegaard, 2018; Odegaard, Chang, et al., 2018; Rahnev et al., 2011; Solovey et al., 2015). This has led to some skepticism about whether subjective inflation is relevant for everyday vision, leading to more recent studies tackling the robustness and generalizability of the effect. These efforts include a study of color sensitivity using naturalistic images, which showed that observers' bias to over-report color in the periphery scaled with the aperture of color in chimera images with a colored center and greyscaled periphery (Okubo & Yokosawa, 2023). Likewise, in the studies reported by Tian, Maniscalco and colleagues (Tian et al., 2025), subjective inflation was found for suprathreshold grating orientation discrimination for stimulus visibility ("did you see a grating?") but not for the task-relevant feature ("did you see the orientation?"). It is interesting to note that these apparent differences in the quantitative relationship between accuracy and confidence for task-relevant versus task-irrelevant stimulus manipulations have also recently been reported by other groups (Fung, Shekhar, Xue, Rausch, & Rahnev, 2025); future work will be required to better understand interactions between task-relevant or irrelevant stimulus manipulations and response prompts in driving accuracy-confidence relationships.

Importantly, our task employs suprathreshold stimuli and observers reported confidence, not visibility, as the subjective measure. We demonstrate that confidence is higher than what performance accuracy would suggest, applied to stimuli that are clearly visible to all observers. This means our results may appear to contradict those reported by Solovey and colleagues 2015, who found that subjective inflation for near-threshold stimuli can be attenuated when stimulus size is adjusted according to cortical magnification (M-scaling), thereby equalizing sensory variability across eccentricity. In the present study, stimuli were not M-scaled, and thus peripheral representations may have remained noisier than parafoveal representations at the sensory level.

Our findings have important implications for how perceptual confidence is understood and modeled. Many accounts implicitly assume that confidence reflects the precision or reliability of the underlying sensory representation or decision variable, such that increases in signal quality should monotonically increase confidence (Boundy-Singer et al., 2023; Fleming, 2024). Our results challenge this assumption by showing that confidence depends on multiple interacting sources of uncertainty or noise, including stimulus reliability, stimulus strength, and spatial location, in ways that are not reducible to objective performance alone. These robust dissociations suggest that subjective confidence is shaped by structured complexities in how perceptual evidence is evaluated, rather than serving as a simple readout of accuracy or internal noise.

Understanding these complex interactions is critical for theories of confidence, metacognition, and decision-making that aim to explain how observers evaluate their perceptual experiences in everyday settings. Specifically, recent theoretical work has emphasized that dissociations between confidence and accuracy should not be treated as anomalies, but rather as informative signatures of how confidence is computed (Peters, 2022; Rahnev, 2025). In this framework, confidence–accuracy dissociations can arise from multiple loci, including pre-decisional sensory encoding, decision-level evidence accumulation, and post-decisional confidence readout. Importantly, the presence of a dissociation alone is insufficient to localize its underlying mechanism, as similar behavioral patterns may emerge from distinct computational processes. Instead, empirical findings constrain the class of models that can account for confidence judgments under uncertainty (Rong & Peters, 2023). Here, we observed effects of stimulus magnitude and reliability, and of visual field location – which are compatible with *both* decisional accounts that emphasize evidence accumulation dynamics and evidence weighting, and pre-decisional accounts involving attentional modulation or differential encoding across the visual field where both of these components may impact the reliability of the underlying visual representations. Although our results cannot adjudicate among such accounts – as noted by Rahnev (2025) – they nevertheless add to the growing body of empirical data that may be used to adjudicate such accounts in future.

To this end, our novel effects of polar angle as well as eccentricity on the relationship between performance and confidence may especially contribute to these ongoing debates. Specifically, in Experiment 1, we observed higher performance-controlled confidence in the vertical periphery compared to the vertical center, at low levels of stimulus noise and low overall luminance. However, this difference was not observed along the horizontal meridian. In other words, mean confidence covaried with stimulus- and eccentricity-induced performance changes in both the horizontal center and the horizontal periphery. Similarly, we also observed that mean confidence covaried with stimulus- and meridian-induced performance changes within the periphery, i.e. when comparing vertical versus horizontal peripheral locations. The differences in the performance-confidence relationship thus primarily appear when comparing parafoveal to peripheral confidence, especially in Experiment 2: performance-controlled confidence was clearly higher in the periphery, mirroring the effects seen in the low-noise, low-luminance condition in Experiment 1. (Note: direct comparisons unfortunately cannot be made between Experiments 1 and 2 because the number of trials and conditions are not matched.)

Several limitations and boundary conditions of the present work warrant consideration. First, although we manipulated stimulus location across eccentricity and polar angle, we did not directly measure, control, or manipulate the spatial extent of attentional allocation. In particular, our use of parafoveal (2 dva) versus peripheral (8 dva) stimuli presented *across* the whole visual field – rather than, for example, at a single 8 dva location – may have created differences in the *extent* of the spatial envelope of visual attention which may have further interacted with stimulus reliability or strength in addition to eccentricity itself (Eriksen & St. James, 1986; Reynolds & Heeger, 2009). However, if anything, we believe the significantly larger spatial attention envelope in the 8 dva condition could have further degraded internal representations in the peripheral conditions rather than enhancing them – and that our performance-matching analytic approaches would account for any changes in performance related to this increased noise. Future work that more explicitly controls for or measures the extent of spatial attention would help clarify the contribution of attentional factors to performance-matched confidence differences.

Second, the generality of the present findings may be constrained by task and stimulus characteristics. We examined confidence in a perceptual comparison task involving luminance-modulated stimuli and time-extended evidence accumulation, following work established by Ko et al. (2022). While this design allowed us to probe confidence under suprathreshold conditions and across multiple sources of uncertainty, subjective inflation may depend on the specific stimulus dimension, decision structure, or response demands of the task. For example, confidence biases may differ for tasks involving categorical judgments, feature detection, or continuous estimation, or when uncertainty is introduced along different stimulus dimensions (as done by (Fung et al., 2025)). Thus, while the present results demonstrate robust confidence-accuracy dissociations under a particular set of conditions, further work is needed to determine the extent to which these effects generalize across tasks, stimulus domains, and decision contexts.

In summary, the present work demonstrates that subjective confidence can dissociate systematically from objective performance under matched accuracy range, and that these dissociations depend on interacting sources of uncertainty, including stimulus reliability, stimulus strength, and spatial location. Extending previous findings, we show that subjective inflation can be observed in a task where decision information accumulates with time, and that it generalizes beyond contrast sensitivity to include luminance as the stimulus dimension, thereby probing brightness perception. Finally, in addition to effects of eccentricity, we show that performance-controlled confidence can vary as a function of polar angle, revealing structured spatial asymmetries in confidence that are not captured by eccentricity alone. Thus, by combining suprathreshold stimuli, time-extended evidence accumulation, and performance-range matching, this study extends prior demonstrations of subjective inflation beyond near-threshold paradigms and single-source manipulations of uncertainty. More broadly, these findings highlight the need for models of perceptual confidence that account for how multiple sources of information – including spatially structured visual field properties – are integrated and weighted when observers evaluate their own perceptual decisions.

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APPENDIX

The following tables use these abbreviations:

- loc = location meridian
- ecc = eccentricity
- noise = stimulus noise
- lumi = overall luminance

EXPERIMENT 1 RESULTS TABLES

4-way (loc × ecc × noise × lumi) repeated measures ANOVAs

RPF rAUC

RPF rAUC			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	1.382	0.278	0.165
ecc	2.217×10^{-5}	0.996	3.167×10^{-6}
noise	8.906	0.020*	0.560
lumi	4.600	0.069	0.397
loc × ecc	1.077	0.334	0.133
loc × noise	2.079	0.193	0.229
ecc × noise	3.842	0.091	0.354
loc × lumi	0.062	0.810	0.009
ecc × lumi	3.569	0.101	0.338
noise × lumi	6.499	0.038*	0.481
loc × ecc × noise	0.915	0.371	0.116
loc × ecc × lumi	9.614	0.017*	0.579
loc × noise × lumi	1.481	0.263	0.175
ecc × noise × lumi	0.263	0.624	0.036
loc × ecc × noise × lumi	6.194	0.042*	0.469

RPF $\bar{P}_2$

RPF $\bar{P}_2$			
Within-subjects effects	$F(1,7)$	p	η_{p}^2
loc	0.769	0.410	0.099
ecc	0.009	0.925	0.001
noise	10.543	0.014*	0.601
lumi	5.922	0.045*	0.458
loc × ecc	1.781	0.224	0.203
loc × noise	3.045	0.125	0.303
ecc × noise	5.207	0.056	0.427
loc × lumi	9.418×10^{-4}	0.976	1.345×10^{-4}
ecc × lumi	7.166	0.032*	0.506
noise × lumi	8.003	0.025*	0.533
loc × ecc × noise	3.506	0.103	0.334
loc × ecc × lumi	5.941	0.045*	0.459
loc × noise × lumi	1.791	0.223	0.204
ecc × noise × lumi	0.724	0.423	0.094
loc × ecc × noise × lumi	9.740	0.017*	0.582

zlog(RT) for the luminance comparison decision

Reaction Time (zlogRT) for luminance comparison decision			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	2.986	0.128	0.299
ecc	12.342	0.010*	0.638
noise	0.014	0.910	0.002
lumi	0.694	0.432	0.090
loc × ecc	0.034	0.859	0.005
loc × noise	4.131	0.082	0.371
ecc × noise	0.149	0.711	0.021
loc × lumi	0.022	0.886	0.003
ecc × lumi	1.840	0.217	0.208
noise × lumi	0.915	0.371	0.116
loc × ecc × noise	0.468	0.516	0.063
loc × ecc × lumi	0.506	0.500	0.067
loc × noise × lumi	4.094	0.083	0.369
ecc × noise × lumi	0.057	0.818	0.008
loc × ecc × noise × lumi	0.048	0.833	0.007

zlog(RT) for confidence rating

Reaction Time (zlogRT) for confidence rating			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	0.057	0.819	0.008
ecc	4.262	0.078	0.378
noise	0.161	0.700	0.022
lumi	0.482	0.510	0.064
loc × ecc	6.124	0.043*	0.467
loc × noise	0.026	0.877	0.004
ecc × noise	0.112	0.747	0.016
loc × lumi	0.035	0.856	0.005
ecc × lumi	0.020	0.892	0.003
noise × lumi	4.151×10^{-5}	0.995	5.930×10^{-6}
loc × ecc × noise	0.195	0.672	0.027
loc × ecc × lumi	0.122	0.737	0.017
loc × noise × lumi	1.666	0.238	0.192
ecc × noise × lumi	1.205	0.309	0.147
loc × ecc × noise × lumi	1.457	0.267	0.172

Low noise, low luminance condition: 2-way (loc × ecc) repeated measures ANOVAs

RPF rAUC

RPF rAUC			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	1.000	0.351	0.125
ecc	3.226	0.116	0.316
loc × ecc	4.492	0.072	0.391

RPF $\bar{P}_2$

RPF $\bar{P}_2$			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	0.066	0.805	0.009
ecc	3.226	0.116	0.316
loc × ecc	5.704	0.048*	0.449

Low noise, high luminance condition: 2-way (loc × ecc) repeated measures ANOVAs

RPF rAUC

RPF rAUC			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	0.300	0.601	0.041
ecc	0.093	0.769	0.013
loc × ecc	0.016	0.903	0.002

RPF $\bar{P}_2$

RPF $\bar{P}_2$			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	0.479	0.511	0.064
ecc	0.103	0.758	0.014
loc × ecc	0.042	0.844	0.006

High noise, low luminance condition: 2-way (loc × ecc) repeated measures ANOVAs

RPF rAUC

RPF rAUC			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	1.611	0.245	0.187
ecc	0.263	0.624	0.036
loc × ecc	0.246	0.635	0.034

RPF $\bar{P}_2$

RPF $\bar{P}_2$			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	0.141	0.719	0.020
ecc	0.009	0.928	0.001
loc × ecc	0.784	0.405	0.101

High noise, high luminance condition: 2-way (loc × ecc) repeated measures ANOVAs

RPF rAUC

RPF rAUC			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	2.010	0.199	0.223
ecc	0.574	0.473	0.076
loc × ecc	0.364	0.565	0.049

RPF $\bar{P}_2$

RPF $\bar{P}_2$			
Within-subjects effects	$F(1,7)$	p	η_p^2
loc	2.886	0.133	0.292
ecc	0.784	0.405	0.101
loc × ecc	1.037	0.342	0.129

Experiment 2 Results tables

2-way (location loc × ecc) repeated mesasures ANOVA on RPF rAUC

RPF rAUC			
Within-subjects effects	$F(1,16)$	p	η^2_p
loc	0.235	0.634	0.014
ecc	4.841	0.043*	0.232
loc × ecc	0.077	0.785	0.005

2-way (location loc × ecc) repeated measures ANOVA on RPF $\bar{P}_2$

RPF $\bar{P}_2$			
Within-subjects effects	$F(1,16)$	p	η^2_p
loc	0.048	0.829	0.003
ecc	5.526	0.032*	0.257
loc × ecc	9.835×10^{-5}	0.992	6.147×10^{-6}

2-way (location loc × ecc) repeated measures ANOVA on luminance decision zlog(RT)

Reaction Time (zlogRT) for luminance comparison decision			
Within-subjects effects	$F(1,16)$	p	η^2_p
loc	0.018	0.895	0.001
ecc	24.829	<0.001*	0.608
loc × ecc	1.128	0.304	0.066

2-way (location loc × ecc) repeated measures ANOVA on confidence rating zlog(RT)

Reaction Time (zlogRT) for confidence rating			
Within-subjects effects	$F(1,16)$	p	η^2_p
loc	0.715	0.399	0.045
ecc	1.051	0.321	0.062
loc × ecc	0.827	0.377	0.049

References

Adler, W. T., & Ma, W. J. (2018). Comparing bayesian and non-bayesian accounts of human confidence reports. *PLoS Computational Biology*, *14*(11), e1006572.

Aitchison, L., Bang, D., Bahrami, B., & Latham, P. E. (2015). Doubly bayesian analysis of confidence in perceptual decision-making. *PLoS computational biology*, *11*(10), e1004519.

Altpeter, E., Mackeben, M., & Trauzettel-Klosinski, S. (2000). The importance of sustained attention for patients with maculopathies. *Vision Research*, *40*(10-12), 1539–1547.

Baranski, J. V., & Petrusic, W. M. (1994). The calibration and resolution of confidence in perceptual judgments. *Perception & Psychophysics*, *55*(4), 412–428.

Barbot, A., Xue, S., & Carrasco, M. (2021). Asymmetries in visual acuity around the visual field. *Journal of Vision*, *21*(1), 2–2.

Boldt, A., de Gardelle, V., & Yeung, N. (2017). The impact of evidence reliability on sensitivity and bias in decision confidence. *Journal of Experimental Psychology: Human Perception and Performance*, *43*(8), 1520–1531.

Boldt, A., Sun, Y., & Desender, K. (2025). How disconfirmatory evidence shapes confidence in decision-making. *Communications Psychology*, *3*(1), 150.

Boundy-Singer, Z. M., Ziemba, C. M., & Goris, R. L. (2023). Confidence reflects a noisy decision reliability estimate. *Nature Human Behaviour*, *7*(1), 142–154.

Carrasco, M., McElree, B., Denisova, K., & Giordano, A. M. (2003). Speed of visual processing increases with eccentricity. *Nature Neuroscience*, *6*(7), 699–700.

Carrasco, M., Talgar, C. P., & Cameron, E. L. (2001). Characterizing visual performance fields: Effects of transient covert attention, spatial frequency, eccentricity, task and set size. *Spatial Vision*, *15*(1), 61.

Cleeremans, A., Timmermans, B., & Pasquali, A. (2007). Consciousness and metarepresentation: A computational sketch. *Neural Networks*, *20*(9), 1032–1039.

Desender, K., Boldt, A., & Yeung, N. (2018). Subjective confidence predicts information seeking in decision making. *Psychological Science*, *29*(5), 761–778.

Eriksen, C. W., & St. James, J. D. (1986). Visual attention within and around the field of focal attention: A zoom lens model. *Perception & psychophysics*, *40*(4), 225–240.

Fetsch, C. R., Kiani, R., Newsome, W. T., & Shadlen, M. N. (2014). Effects of cortical microstimulation on confidence in a perceptual decision. *Neuron*, *83*(4), 797–804.

Fleming, S. M. (2024). Metacognition and confidence: A review and synthesis. *Annual Review of Psychology*, *75*(1), 241–268.

Fleming, S. M., & Daw, N. D. (2017). Self-evaluation of decision-making: A general bayesian framework for metacognitive computation. *Psychological Review*, *124*(1), 91.

Fung, H., Shekhar, M., Xue, K., Rausch, M., & Rahnev, D. (2025). Similarities and differences in the effects of different stimulus manipulations on accuracy and confidence. *Consciousness and cognition*, *136*, 103942.

Hangya, B., Sanders, J. I., & Kepecs, A. (2016). A mathematical framework for statistical decision confidence. *Neural Computation*, *28*(9), 1840–1858.

Hellmann, S., Zehetleitner, M., & Rausch, M. (2024). Confidence is influenced by evidence accumulation time in dynamical decision models. *Computational Brain & Behavior*, *7*(3), 287–313.

Herce Castañón, S., Moran, R., Ding, J., Egner, T., Bang, D., & Summerfield, C. (2019). Human noise blindness drives suboptimal cognitive inference. *Nature Communications*, *10*(1), 1719.

Himmelberg, M. M., Winawer, J., & Carrasco, M. (2023). Polar angle asymmetries in visual perception and neural architecture. *Trends in Neurosciences*, *46*(6), 445–458.

Jang, Y., Wallsten, T. S., & Huber, D. E. (2012). A stochastic detection and retrieval model for the study of metacognition. *Psychological Review*, *119*(1), 186.

Jovanovic, L., & Mamassian, P. (2019). When an event is perceived depends on where we attend. *i-Perception*, *10*(3), 2041669519858096.

Kiani, R., Corthell, L., & Shadlen, M. N. (2014). Choice certainty is informed by both evidence and decision time. *Neuron*, *84*(6), 1329–1342.

Ko, Y. H., Feuerriegel, D., Turner, W., Overhoff, H., Niessen, E., Stahl, J., … Bode, S. (2022). Divergent effects of absolute evidence magnitude on decision accuracy and confidence in perceptual judgements. *Cognition*, *225*, 105125.

Koizumi, A., Maniscalco, B., & Lau, H. (2015). Does perceptual confidence facilitate cognitive control? *Attention, Perception, & Psychophysics*, *77*, 1295–1306.

Lau, H. C., & Passingham, R. E. (2006). Relative blindsight in normal observers and the neural correlate of visual consciousness. *Proceedings of the National Academy of Sciences*, *103*(49), 18763–18768.

Li, M. K., Lau, H., & Odegaard, B. (2018). An investigation of detection biases in the unattended periphery during simulated driving. *Attention, Perception, & Psychophysics*, *80*, 1325–1332.

Mackeben, M. (1999). Sustained focal attention and peripheral letter recognition. *Spatial Vision*, *12*(1), 51–72.

Mamassian, P. (2016). Visual confidence. *Annual Review of Vision Science*, *2*, 459–481.

Maniscalco, B., Graham Castaneda, O., Odegaard, B., Morales, J., Rajananda, S., Denison, R. N., & Peters, M. A. (2026). The relative psychometric function: a general analysis framework for relating psychological processes. *Psychological Review*.

Maniscalco, B., & Lau, H. (2016). The signal processing architecture underlying subjective reports of sensory awareness. *Neuroscience of Consciousness*, *2016*(1), niw002.

Maniscalco, B., Odegaard, B., Grimaldi, P., Cho, S. H., Basso, M. A., Lau, H., & Peters, M. A. (2021). Tuned inhibition in perceptual decision-making circuits can explain seemingly suboptimal confidence behavior. *PLoS Computational Biology*, *17*(3), e1008779.

Maniscalco, B., Peters, M. A., & Lau, H. (2016). Heuristic use of perceptual evidence leads to dissociation between performance and metacognitive sensitivity. *Attention, Perception, & Psychophysics*, *78*, 923–937.

Miyoshi, K., & Lau, H. (2020). A decision-congruent heuristic gives superior metacognitive sensitivity under realistic variance assumptions. *Psychological Review*, *127*(5), 655.

Miyoshi, K., Webb, T., Rahnev, D., & Lau, H. (2024). Confidence and metacognition. *Reference Module in Neuroscience and Biobehavioral Psychology. Elsevier*, *10*.

Morales, J., Odegaard, B., & Maniscalco, B. (2022). 10 the neural substrates of conscious perception without performance confounds. *Neuroscience and Philosophy*, 285.

Moran, R., Teodorescu, A. R., & Usher, M. (2015). Post choice information integration as a causal determinant of confidence: Novel data and a computational account. *Cognitive Psychology*, *78*, 99–147.

Odegaard, B., Chang, M. Y., Lau, H., & Cheung, S.-H. (2018). Inflation versus filling-in: why we feel we see more than we actually do in peripheral vision. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *373*(1755), 20170345.

Odegaard, B., Grimaldi, P., Cho, S. H., Peters, M. A., Lau, H., & Basso, M. A. (2018). Superior colliculus neuronal ensemble activity signals optimal rather than subjective confidence. *Proceedings of the National Academy of Sciences*, *115*(7), E1588–E1597.

Okubo, L., Miyoshi, K., Yokosawa, K., & Nishida, S. (2026). Inattentional noise leads to subjective color uniformity across the visual field. *Cognition*, *266*, 106293.

Okubo, L., & Yokosawa, K. (2023). Attentional allocation and the pan-field color illusion. *Journal of Vision*, *23*(3), 13–13.

Pereira, M., Faivre, N., Iturrate, I., Wirthlin, M., Serafini, L., Martin, S., ... Millán, J. d. R. (2020). Disentangling the origins of confidence in speeded perceptual judgments through multimodal imaging. *Proceedings of the National Academy of Sciences*, *117*(15), 8382–8390.

Peters, M. A. (2022). Towards characterizing the canonical computations generating phenomenal experience. *Neuroscience & Biobehavioral Reviews*, 104903.

Peters, M. A., Fesi, J., Amendi, N., Knotts, J. D., Lau, H., & Ro, T. (2017). Transcranial magnetic stimulation to visual cortex induces suboptimal introspection. *Cortex*, *93*, 119–132.

Peters, M. A., Thesen, T., Ko, Y. D., Maniscalco, B., Carlson, C., Davidson, M., ... Lau, H. (2017). Perceptual confidence neglects decision-incongruent evidence in the brain. *Nature Human Behaviour*, *1*(7), 0139.

Pleskac, T. J., & Busemeyer, J. R. (2010). Two-stage dynamic signal detection: a theory of choice, decision time, and confidence. *Psychological Review*, *117*(3), 864.

Pruitt, J., Knotts, J., & Odegaard, B. (2024). Consistent metacognitive efficiency and variable response biases in peripheral vision. *Journal of Vision*, *24*(8), 4–4.

Rahnev, D. A. (2021). Visual metacognition: Measures, models, and neural correlates. *American Psychologist*, *76*(9), 1445.

Rahnev, D. A. (2025). Confidence-accuracy dissociations in perceptual decision making. *PsyArXiv*.

Rahnev, D. A., Maniscalco, B., Graves, T., Huang, E., De Lange, F. P., & Lau, H. (2011). Attention induces conservative subjective biases in visual perception. *Nature Neuroscience*, *14*(12), 1513–1515.

Rahnev, D. A., Maniscalco, B., Luber, B., Lau, H., & Lisanby, S. H. (2012). Direct injection of noise to the visual cortex decreases accuracy but increases decision confidence. *Journal of Neurophysiology*, *107*(6), 1556–1563.

Rajananda, S., Peters, M. A., Lau, H., & Odegaard, B. (2017). Subjective inflation of color saturation in the periphery under temporal overload. *BioRxiv*, 227074.

Rausch, M., Hellmann, S., & Zehetleitner, M. (2018). Confidence in masked orientation judgments is informed by both evidence and visibility. *Attention, Perception, & Psychophysics*, *80*, 134–154.

Rausch, M., Hellmann, S., & Zehetleitner, M. (2021). Modelling visibility judgments using models of decision confidence. *Attention, Perception, & Psychophysics*, *83*(8), 3311–3336.

Reynolds, J. H., & Heeger, D. J. (2009). The normalization model of attention. *Neuron*, *61*(2), 168–185.

Rong, Y., & Peters, M. A. (2023). Toward 'computational-rationality'approaches to arbitrating models of cognition: A case study using perceptual metacognition. *Open Mind*, *7*, 652–674.

Rounis, E., Maniscalco, B., Rothwell, J. C., Passingham, R. E., & Lau, H. (2010). Theta-burst transcranial magnetic stimulation to the prefrontal cortex impairs metacognitive visual awareness. *Cognitive Neuroscience*, *1*(3), 165–175.

Samaha, J., Barrett, J. J., Sheldon, A. D., LaRocque, J. J., & Postle, B. R. (2016). Dissociating perceptual confidence from discrimination accuracy reveals no influence of metacognitive awareness on working memory. *Frontiers in Psychology*, *7*, 851.

Samaha, J., & Denison, R. (2022). The positive evidence bias in perceptual confidence is unlikely post-decisional. *Neuroscience of Consciousness*, *2022*(1), niac010.

Samaha, J., Iemi, L., & Postle, B. R. (2017). Prestimulus alpha-band power biases visual discrimination confidence, but not accuracy. *Consciousness and Cognition*, *54*, 47–55.

Samaha, J., Switzky, M., & Postle, B. R. (2019). Confidence boosts serial dependence in orientation estimation. *Journal of Vision*, *19*(4), 25–25.

Sharvashidze, N., Toscani, M., & Valsecchi, M. (2025). Peripheral overconfidence in a scene categorization task. *Journal of Vision*, *25*(10), 2–2.

Shekhar, M., & Rahnev, D. (2021). The nature of metacognitive inefficiency in perceptual decision making.

Psychological review, *128*(1), 45.
Solovey, G., Graney, G. G., & Lau, H. (2015). A decisional account of subjective inflation of visual perception at the periphery. *Attention, Perception, & Psychophysics*, *77*, 258–271.
Strasburger, H., Rentschler, I., & Jüttner, M. (2011). Peripheral vision and pattern recognition: A review. *Journal of Vision*, *11*(5), 1–82.
Tian, K. J., Maniscalco, B., Epstein, M. L., Shen, A., Castaneda, O. G., Kurosawa, T., … others (2025). Attention robustly dissociates objective performance and subjective visibility reports. *bioRxiv*, 2025–07.
Toscani, M., Mamassian, P., & Valsecchi, M. (2021). Underconfidence in peripheral vision. *Journal of Vision*, *21*(6), 2–2.
Upadhyayula, A., Phillips, I., & Flombaum, J. (2023). Eccentricity advances arrival to visual perception. *Journal of Experimental Psychology: General*.
Yeung, N., & Summerfield, C. (2012). Metacognition in human decision-making: confidence and error monitoring. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *367*(1594), 1310–1321.
Zylberberg, A., Barttfeld, P., & Sigman, M. (2012). The construction of confidence in a perceptual decision. *Frontiers in Integrative neuroscience*, *6*, 79.
Zylberberg, A., Fetsch, C. R., & Shadlen, M. N. (2016). The influence of evidence volatility on choice, reaction time and confidence in a perceptual decision. *Elife*, *5*, e17688.
Zylberberg, A., Roelfsema, P. R., & Sigman, M. (2014). Variance misperception explains illusions of confidence in simple perceptual decisions. *Consciousness and Cognition*, *27*, 246–253.