Reducible and irreducible uncertainty in low-level visual representations

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Abstract: Recent studies suggested that humans utilize uncertainty for optimal decisions (Koblinger et al., 2020a; Fiser et al., 2010; Tóth & Jazayeri, 2014). However, there exist two different kinds of uncertainties that have not been systematically distinguished or treated separately before in the literature: reducible and irreducible.

Reducible uncertainty is a fundamental aspect of probabilistic encoding that originates from the probabilistic representation of the sensory input. Proper treatment of probabilistic computation handles both types of uncertainties. Yet, typical probabilistic frameworks of cognition discuss only the reducible part of uncertainty (Gold & Shadlen, 2007).

To address this issue, we measured the extent to which a human perceptual certainty can be fully calibrated, shown by the high correlation between error and certainty. New results: With modified contrast levels and stimulus type, the asymptotic behavior of both accuracy and certainty decisions are modulated by the contrast and set size, indicating the encoding of the inherent ambiguity in the input item.

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References & Acknowledgements

Figure 1: Response: Orientation & confidence with drawing a single line

Figure 2: Presentation time & confidence

Figure 3: Time dependence: Both accuracy and certainty increase over time and are on the same scale.

Figure 4: Well-calibrated: Uncertainty representations are well-calibrated, shown by the high correlation between error and certainty.

Figure 5: Experimental design

Figure 6: Results I: Time dependence & well-calibration

Figure 7: Results II: Evidence for irreducible uncertainty

Figure 8: Experimental design

Figure 9: Results I: Time dependence & well-calibration

Figure 10: Results II: Evidence for irreducible uncertainty

Results III: Uncertainty depending predominantly on low-level probabilistic internal representation

Question: Does the reported uncertainty rely directly on a simple internal low-level representation (LLR), or is it predominantly based on explicit, high-level quantification of external cues such as set size, contrast, presentation time, etc.? (Koblinger et al., 2021)

Answer: Check for hallmarks of uncertainty being determined by low-level probabilistic internal representation via simulations.

Signatures of LLR-based certainty reports

- Simulation I: No modulation of certainty at short presentation times (MSRT) decrease of certainty at zero-information condition over time.

- LLR certainty: handled at low samples and negative slope at zero information.

- HLQ certainty: separated at low samples and flat zero at zero information.

- No difference between LLR and HLQ.

- LLR certainty: regression to the mean.

- HLQ certainty: no deviations.

- Humans utilize their perceptual uncertainty in a well-calibrated manner during perceptual judgments even in the case of simple stimuli such as lines or Gabber patches.

- Perceptual judgments handled not only reducible but also irreducible uncertainties.

- Since uncertainty in our task is already encoded at a low perceptual level in parallel for multiple elements, our results suggest that human internal representation is fully probabilistic (Koblinger et al., 2021).

Conclusion

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More details are available in the full text of this proceedings.