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Signatures of a Statistical Computation in the Human Sense of Confidence

Highlights

- Statistical principles govern how evidence informs the formation of human confidence
- Human confidence reports follow qualitative predictions of statistical confidence
- With one noise parameter we provide a quantitative account of confidence reports

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In Brief

Sanders et al. show that human confidence judgments originate from the mental computation of statistical confidence in both a perceptual and a knowledge-based decision task.

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Signatures of a Statistical Computation in the Human Sense of Confidence

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SUMMARY

Human confidence judgments are thought to originate from metacognitive processes that provide a subjective assessment about one's beliefs. Alternatively, confidence is framed in mathematics as an objective statistical quantity: the probability that a chosen hypothesis is correct. Despite similar terminology, it remains unclear whether the subjective feeling of confidence is related to the objective, statistical computation of confidence. To address this, we collected confidence reports from humans performing perceptual and knowledge-based psychometric decision tasks. We observed two counterintuitive patterns relating confidence to choice and evidence: apparent overconfidence in choices based on uninformative evidence, and decreasing confidence with increasing evidence strength for erroneous choices. We show that these patterns lawfully arise from statistical confidence, and therefore occur even for perfectly calibrated confidence measures. Furthermore, statistical confidence quantitatively accounted for human confidence in our tasks without necessitating heuristic operations. Accordingly, we suggest that the human feeling of confidence originates from a mental computation of statistical confidence.

INTRODUCTION

The scientific study of confidence has emerged from different traditions, reflecting its dual manifestation as a subjective feeling and an objective forecast. In the psychological tradition, confidence is thought to arise from the monitoring of mental content; it is sometimes framed as a form of metacognition associated with other subjective human qualities, such as introspection, awareness, and even self-reflective consciousness (Charles et al., 2013; Flavell, 1979; Kunimoto et al., 2001; Lau and Rosenthal, 2011; Metcalfe and Shimamura, 1994). A wealth of studies has confirmed that humans possess this ability, and have identified conditions under which confidence appears to be miscalibrated, predicting outcomes sub-optimally (Bar-Tal et al., 2001; Baranski and Petrusic, 1994; Björkman et al., 1993; Camerer and Lovallo, 1999; Griffin and Tversky, 1992; Juslin et al., 2000; Kvidera and Koutstaal, 2008; Moore and Healy, 2008; Olsson and Winman, 1996; Shea et al., 2014; Stankov, 1998). In fact, human confidence often does not appear to reflect the underlying performance, suggesting that it is generated by an error-prone heuristic computation (Gigerenzer and Goldstein, 1996; Koriat, 2012; Tversky and Kahneman, 1974).

A separate construct termed "confidence" has also been studied in many disciplines as a wholly objective mathematical quantity. Formally defined as the Bayesian posterior probability that a decision-maker is correct, confidence refers to a computational tool used in statistical analysis to assess hypotheses based on noisy or unreliable evidence. This confidence formulation is central to statistical decision theory and can be exploited to improve machine learning algorithms (Schapire and Singer, 1999; Sollich, 2002). Statistical models have also been used successfully to account for the perceptual and motor systems in decision-making, which obey Bayesian principles when faced with uncertainty (Ernst and Banks, 2002; Fetsch et al., 2013; Fiser et al., 2010; Körding and Wolpert, 2004; Pouget et al., 2013; Stocker and Simoncelli, 2006; Trommershäuser et al., 2008). However, less is known about the degree to which these same principles can account for central cognitive processes such as confidence (Kepecs et al., 2008; Kiani and Shadlen, 2009; Komura et al., 2013; Tenenbaum et al., 2011).

The idea that the subjective sense of confidence avails a statistical likelihood readout to the decision-maker has been suggested only sparsely as a conjecture (Griffin and Tversky, 1992). Indeed, the Bayesian confidence computation is often the de facto working assumption in economic studies when comparing human confidence to an ideal accuracy predictor. However, numerous attempts to model human confidence algorithmically have only considered indirect correlates such as reaction time (Audley, 1960; Kiani et al., 2014), decision variable balance (De Martino et al., 2013; Drugowitsch et al., 2014; Insabato et al., 2010; Kepecs et al., 2008; Vickers, 1979; Wei and Wang, 2015), decision variable variance (Yeung and Summerfield, 2012), and post-decisional deliberation (Pleskac and Busemeyer, 2010). These models have successfully accounted for a range of psychometric and chronometric aspects of human confidence. Importantly, these algorithmic models can make qualitatively different predictions depending on parameter choices, and no unifying predictions have emerged that directly relate these models with statistical confidence (Pouget et al., 2016).