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Normative and Informational Confidence Matching

Maja Friedemann[1, 2], Dan Bang[1, 3, 4, 5], and Nick Yeung[1]
[1] Department of Experimental Psychology, University of Oxford
[2] Wellcome Centre for Integrative Neuroimaging, University of Oxford
[3] Center of Functionally Integrative Neuroscience, Aarhus University
[4] Fralin Biomedical Research Institute, Virginia Tech
[5] Wellcome Centre for Human Neuroimaging, University College London

When performing tasks in a social context, individuals tend to report confidence judgments that increasingly align with those of others over time. However, the mechanisms underlying this phenomenon, termed *confidence matching*, are not fully understood. This study explores two potential drivers of confidence matching behavior: informational factors that cause individuals to genuinely recalibrate their private sense of confidence based on their partner's confidence; and normative factors that lead individuals to adapt the way in which they publicly express their confidence, without changing their private assessment of their own performance. To examine these influences, we conducted two experiments examining the effects of both informational and normative factors on private and public confidence. The results demonstrate that both factors can lead to confidence matching. In a setting devoid of feedback, participants matched their confidence reports with their partner's and modified their information-seeking behavior—a proxy for private confidence—accordingly, pointing toward the role of informational factors. Conversely, in a scenario in which feedback was readily available and a joint decision-making rule was enforced, participants aligned their confidence reports with their partner's but did not adjust their information-seeking behavior, hinting at normative factors influencing the public display of confidence matching. These findings highlight the flexibility and context-sensitivity of confidence, thereby underscoring the importance of factoring in social contexts and the adaptive nature of confidence when studying metacognitive processes.

Public Significance Statement
This research sheds light on how and why people adjust the way they express how confident they are when making decisions with others, a phenomenon known as "confidence matching." Understanding these dynamics is useful for improving decision-making processes in social settings, such as in workplaces, classrooms, or group collaborations. The study reveals that individuals may sometimes genuinely change how confident they feel based on the information they receive from others, and sometimes simply align their overtly expressed confidence to fit in socially, depending on the context. These insights can help in designing environments and practices that foster better group decisions by recognizing and addressing the factors that influence how confidence is communicated and interpreted among individuals.

Keywords: confidence, metacognition, social influences, decision making

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Maja Friedemann https://orcid.org/0000-0003-1506-2135

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Correspondence concerning this article should be addressed to Maja Friedemann, Wellcome Centre for Integrative Neuroimaging, University of Oxford, Tinsley Building, Mansfield Road, Oxford OX1 3SR, United Kingdom. Email: maja.friedemann@psy.ox.ac.uk

The ability to estimate our confidence in the decisions we make is a key feature of adaptive behavior. People reliably judge their own performance in the absence of feedback, with confidence reports closely tracking objective accuracy (Baranski & Petrusic, 1994; Koriat & Goldsmith, 1996). In groups, confidence reports can help identify who is most likely to know the correct answer (Pescetelli et al., 2016), thereby promoting effective group behavior (Shea et al., 2014).

Although an individual's confidence is typically proportional to the probability that their decision or belief is correct, transient factors such as physiological arousal (Allen et al., 2016; Jönsson et al., 2005) and current mood (Koellinger & Treffers, 2015) as well as individual-specific characteristics such as gender (Lundeberg et al., 1994), mental health (Fu et al., 2012), and personality (Campbell et al., 2004; Pallier et al., 2002; Schaefer et al., 2004) also impact confidence reports. In theory, a robust approach to collective decision making involves weighting individual opinions according to the confidence with which they are reported (Bahrami et al., 2010). Indeed, advice-taking studies have demonstrated that an advisor's confidence is the best predictor of their level of influence (Kuhn & Sniezek, 1996; Van Swol & Sniezek, 2002). However, if an individual's confidence is influenced by factors unrelated to their probability of being correct, these confidence variations can disrupt the otherwise constructive impact of confidence-based opinion weighting because the improvement of a group relative to its individual members hinges on the degree to which confidence is calibrated across group members (Silver et al., 2021). Indeed, there are instances where communication may actually increase individual error rates (Kerr & Tindale, 2004; Valeriani et al., 2017) and lead joint decisions to be worse than those of individuals working alone (Koriat, 2012).

Intriguingly, within the context of social decision making, there seems to be a propensity for partners to naturally align their confidence reports whereby, over time, partners report more similar confidence judgements in terms of their average confidence as well as the distribution of confidence reports (Bang et al., 2017; Pescetelli & Yeung, 2020, 2022). This behavior—termed *confidence matching*—is an effective strategy for maximizing joint accuracy when both partners have similar levels of expertise (Bang et al., 2017). However, it remains unclear whether this matching reflects a deeper change in participants' genuine feeling of confidence (henceforth their *private confidence*) or is merely a surface-level adjustment in how they express their confidence to others (henceforth their *public confidence*).

Confidence shifts may be understood through social psychology research on conformity. Informational social influence occurs when individuals mimic others' actions, assuming they reflect correct behavior in uncertain situations (Sherif, 1935). Confidence matching may arise from social learning (Bahrami et al., 2012), where a partner's confidence signals task difficulty, potentially altering one's own private confidence. Conversely, normative social influence involves adjusting observable beliefs or behaviors to align with a group for social acceptance, even if they contradict private convictions (Asch, 1951).

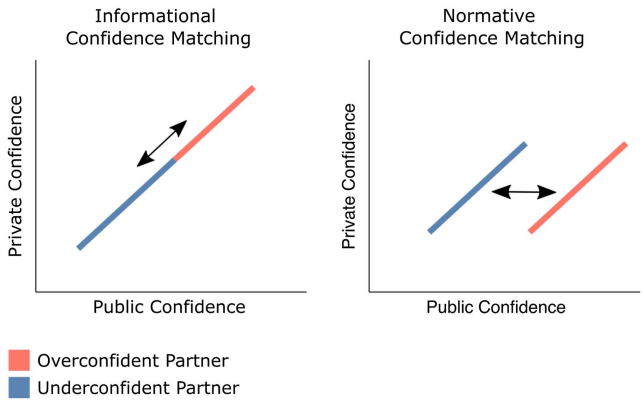
Although confidence cannot entirely replace objective feedback, it still provides a rough but useful estimate of the actual state of the world. The potential contribution of normative influence to confidence matching is particularly clear in tasks using "maximum confidence slating" as the decision rule, where a group's decision is determined by the most confident individual in the group (Bang et al., 2017, 2020; Koriat, 2012): Here, individuals have a direct motive to match their confidence levels so that their opinions are not consistently overlooked or are not always dominating the collective decision. Corfman et al. (1990) suggested that people naturally seek balanced influence in groups to maintain cohesion and effective decision making. Similarly, Mahmoodi et al. (2015) found evidence of this "equality bias" in a controlled perceptual decision-making paradigm similar to the ones used in this study. Thomas et al. (2022) further supported this idea, showing that even young children prefer egalitarian group dynamics.

Even without an explicit decision rule to encourage confidence matching, matching could arise from the informal rule that opinions expressed with higher confidence typically carry more weight in group decisions (Zarnoth & Sniezek, 1997), from a desire for reciprocity and sharing of responsibility across group members (El Zein et al., 2019; Mahmoodi et al., 2018), or indeed from mere imitation (Fusaroli et al., 2012; Pickering & Garrod, 2004). The findings of Bang et al. (2017) suggest that confidence matching is influenced both by context-specific strategic thinking and context-general behavioral imitation. Regardless of the specific mechanisms at play, this interpretation of normative influences implies that there are separable private and public expressions of confidence (Bang et al., 2020).

The differing implications of these two accounts of confidence matching are depicted in Figure 1. When confidence matching is driven by informational factors, individuals adjust their confidence reports to align with their partner's confidence because their own private confidence truly shifts in response to their partner's expressions of high or low confidence—that is, they feel more or less confident according to the social information received, and their reports reflect this change in private confidence. Consequently, the overall relationship between private confidence and public confidence is preserved—the points fall on the same line relating the two in Figure 1—so that both are impacted proportionally by social information. Conversely, when confidence matching is driven by

Figure 1

Confidence Matching Driven by Informational Versus Normative Factors



Note. Under the informational confidence matching view, an increase in public confidence from being paired with an underconfident partner to being paired with an overconfident partner would be in line with an increase in true private confidence. Under the normative confidence matching view, this confidence increase would be at the report level only, causing a change in mapping between private and publicly public confidence. See the online article for the color version of this figure.

normative factors, participants' feelings of confidence do not change, but rather participants change the way they translate their private confidence into a public report in response to interacting with different partners. Consequently, for a given level of experienced uncertainty, a person's confidence reports will vary according to whether they are interacting with a low- versus high-confidence partner.

Importantly, these explanations are not mutually exclusive. Our experiments were designed to test the hypothesis that both informational and normative factors contribute to confidence matching, albeit to varying degrees depending on the context. In the absence of feedback, we predicted that informational factors would predominate. Here, partners' confidence serves as a valuable cue to task difficulty, allowing individuals to calibrate their own judgments. Nonetheless, even in this context, normative influences may still play a subtle role, such that participants are motivated to align their confidence with their partner's not only due to perceived task difficulty but partly because of an underlying desire for social conformity. However, we hypothesized that such normative factors would become dominant when explicit social norms or decision rules are introduced. For instance, in scenarios involving confidence-weighted opinion aggregation, individuals may be more inclined to adjust their public confidence to align with social expectations or to influence the group decision-making process.

To test these hypotheses, participants completed perceptual decision-making tasks alongside virtual partners under two task conditions. In one condition, participants performed the task without any feedback, only observing a partner's choices and confidence reports. Here, we expected the partners' influence to be primarily informational, with partners' expressed confidence providing a cue to task difficulty (which would otherwise be ambiguous given the lack of feedback). In the other condition, participants received trial-by-trial feedback, and both their response and their partner's were entered into maximum confidence slating joint decision rule. Here, we expected primarily normative influence, with participants motivated to match their average confidence to their partner's to avoid one partner's answers dominating the dyad's decisions. Because objective feedback is provided on each trial here, the partner's confidence should add little informational value about task difficulty.

Thus, we anticipated confidence matching behavior in both conditions, assessed in terms of participants' average confidence when paired with partners of low or high average confidence. However, crucially, we expected participants' behavior to differ across conditions on a key subset of trials in which participants had the option to seek additional information before finalizing their decision. Participants' information-seeking choices were used as a behavioral proxy of their private confidence, given previous evidence of strong links between the two (Desender et al., 2018, 2019; Pescetelli et al., 2021). To the degree that confidence matching occurs for different reasons across our informational and normative conditions, we should predict different patterns of information seeking and a different relationship between confidence and information seeking. Specifically, our two key predictions were as follows: (a) In the informational condition (but not the normative one), matching confidence with a partner's confidence reports should change participants' information-seeking behavior: By hypothesis, only in the former condition does confidence matching reflect a change in private confidence that should determine the perceived value of additional information that is presumed to govern information-seeking behavior. (b) In the normative condition (but not the informational one), matching confidence with a partner's confidence reports should change the relationship between confidence reports and information-seeking behavior: By hypothesis, in the normative case, confidence matching occurs without a change in private confidence, which should result in a changed relationship between confidence reports and information seeking when paired with different partners.

These predictions are illustrated in Figure 1, which depicts the effects of the partner on publicly reported versus private confidence. Here, information seeking is used as proxy for the "private confidence" variable. These two predictions were tested together in both experiments reported below. The experiments differed only in whether participants performed the same perceptual decision task in both informational and normative conditions (Experiment 1) or performed different tasks in the two (Experiment 2) as explained in more detail below.

Method

Participants

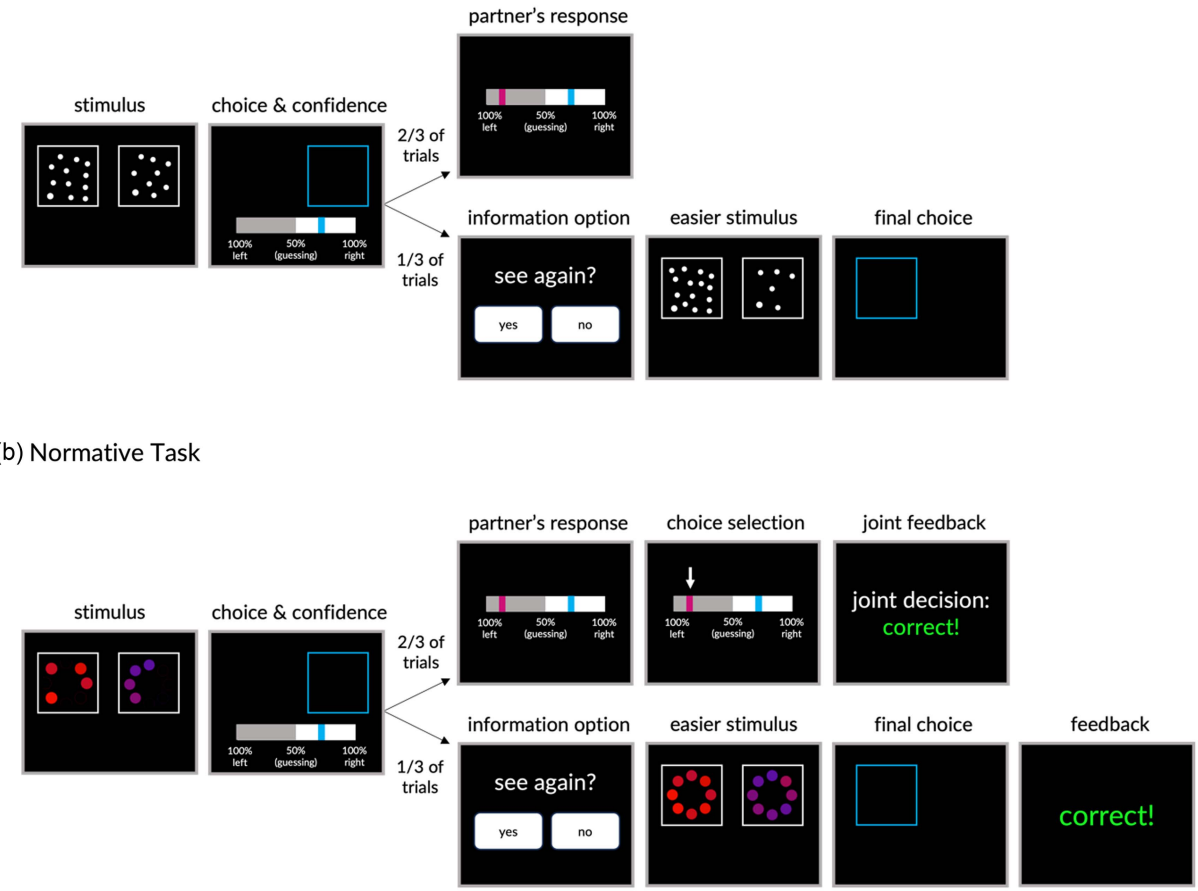
Participants were recruited through the online recruitment platform Prolific (https://www.prolific.com). Experiment 1 was completed by 30 participants. One participant was excluded due to online data saving issues. The remaining sample consisted of 29 participants (17 participants reported their gender as female, 12 as male; $M_{age} \pm SD$: 31.1 ± 9.8 years). Experiment 2 was completed by 60 participants. One participant was excluded due to online data saving issues. The remaining sample consisted of 59 participants (40 participants reported their gender as female, 18 as male, one as other; $M_{age} \pm SD$: 30.2 ± 8.3 years). Demographic information, including age and gender, was collected through a questionnaire. Participants reported their gender by selecting from the following options: "Male," "Female," "other," and "prefer not to say." Age was reported using a slider ranging from 18 to 60. Participants were compensated with a base amount of £10/hr plus an additional reward depending on performance in the tasks. The experiments were approved by the University of Oxford's Medical Sciences Interdivisional Research Ethics Committee (R67369/RE001).

Procedure

Participants in both experiments completed two sessions on separate days, 2–7 days apart, one involving the normative task version and one involving the informational task version (order counterbalanced across participants). Each session involved a series of trials of a perceptual decision task, depicted in Figure 2. In Experiment 1, participants performed the same dot discrimination task (depicted in Figure 2a) in both sessions. In Experiment 2, participants completed the dot discrimination task in one session and a color discrimination task (depicted in Figure 2b) in the other session (order counterbalanced; see below for a description of these tasks). The two experiments were otherwise identical. Experiment 2 aimed to replicate key findings from Experiment 1 with a larger sample size and, critically, while using different tasks in the two sessions to reduce order effects (relating to whether the informational or normative condition was performed first) that were apparent in the first experiment, as described below.

On each trial, participants first reported their decision regarding the perceptual stimuli, then rated how confident they felt in that decision. On a third of trials, participants then had the option to seek

Figure 2
Experimental Design



Note. Participants performed either a dot discrimination task, depicted in Panel (a), or a color discrimination task, depicted in Panel (b), with task assignment counterbalanced across participants. Following an initial decision, participants reported their confidence in the decision on a continuous scale. Subsequently, a partner's response and confidence judgment were revealed in two thirds of the trials. The unique feature of the normative task version, depicted in Panel (b), as compared to the informational task version, depicted in Panel (a), is that the choice reported with higher confidence was taken as the joint decision, with accompanying objective feedback and reward. In one 1wthird of trials, after the initial choice and confidence judgment, participants received a prompt to either seek additional information or progress to the next trial. If additional information was sought, a simplified version of the stimulus was presented, allowing for a final decision. Objective feedback was provided only in the normative task version (Panel b) and not in the informational task version (Panel a). In these examples, the dot discrimination task appears in the informational condition and the color discrimination task is used in the normative condition, but for half of the participants this task condition assignment was reversed. Please note that the task screens are simplified for illustration purposes. The actual dot task stimuli shown to participants contained many more dots than in Panel (a), and the visual analogue confidence scale included equally spaced markers for "maybe LEFT/RIGHT," "probably LEFT/RIGHT" and "certainly LEFT/RIGHT" to facilitate participants' use of the scale, as well as a dynamic slider marker label, showing participants the exact percentage of confidence that they were selecting. As explained in the text, participants were led to believe that the partners were just as good as them at the task; in reality, the partner's accuracy was fixed at 80%. See the online article for the color version of this figure.

further information before committing to a final choice with no cost except for time. On all other trials, participants' choice and confidence rating were followed by the display of a partner's choice and confidence. Participants were paired with one partner in the first half of each session and a different partner in the second half. Participants were told that the partners were past participants completing the same task, who had performed similarly well to them during the practice trials. In reality, and as revealed to participants during debriefing, the partners were computer-generated, with predetermined confidence profiles. Specifically, one of the two partners was designed to be "underconfident," whereas the other partner was designed to be "overconfident" (see details below).

In one of the two sessions, participants completed a normative task version as depicted in Figure 2b. On information-seeking trials, participants were rewarded based on the accuracy of their final decision. On partner trials, the reward was determined by the

accuracy of the joint decision made with their partner, which was arbitrated in favor of whichever partner's decision was reported with higher confidence. Given this maximum confidence slating decision rule, the optimal strategy is to report confidence in a way that maximizes the probability of the joint decision being correct. Therefore, participants should adjust their confidence reports based on their partner's reports, because they otherwise risk having their opinion rarely or never count (when paired with a systematically overconfident partner) or having their opinion dominate the group's decision even when it is unlikely to be correct (when paired with a systematically underconfident partner). Feedback was provided on every trial. In addition, after each set of 25 trials, participants received information about the average accuracy of their own decisions, their partner's decisions, and the joint decisions over the block. Via this extensive feedback, we aimed to minimize the potential informational influence of partners' confidence ratings. When making their initial response, participants did not know whether they were in an information-seeking trial or in a partner trial.

In the other session of an experiment, participants completed an informational task version as depicted in Figure 2a. Just as in the normative task, blocks contained intermixed information-seeking trials and partner trials. For the latter, participants observed their partner's decision and confidence after having reported their own. However, there was no joint decision stage and, importantly, no feedback. Instead, participants were rewarded based on the accuracy of their decisions as well as the precision of their confidence reports according to a Brier score (Brier, 1950). In the case of information-seeking trials, only the final decision was considered for reward. The Brier score is calculated as the squared difference between confidence rating c and decision accuracy o: $\mathrm{BS} = \sum_{i=1}^{n} (c_i - o_i)^2$, where $o \in \{0, 1\}$. Under this scoring rule, participants are incentivized to report their true belief about the probability of their decision being correct, because the rule penalizes differences between predicted probabilities (in this case, the confidence ratings) and the actual outcomes (objective decision accuracy).

Tasks

In the dot discrimination task (performed for both sessions in Experiment 1, and for one session in Experiment 2), participants were asked to decide which of two boxes contains a larger number of dots and rate their confidence in this judgment. Each trial began with a fixation cross displayed for 1,000 ms, followed by the presentation of two black boxes with an unequal number of white dots randomly positioned inside. After 300 ms, the dots disappeared and participants were prompted to make a choice using their mouse, by choosing the left box with a left click or the right box with a right click. Participants then used the mouse to indicate their confidence on a continuous visual analogue scale ranging from 50% (guessing) to 100% (completely certain that the chosen side has more dots). One of the boxes (position counterbalanced) contained 200 dots and the other contained $200 + d$ dots, with $d \in [0, 100]$. The value of d was set via an adaptive staircase procedure in an initial block of 100 practice trials in which only the perceptual decision task was performed (i.e., with no partner response or information seeking after the participants' initial response). During these trials, task difficulty was staircased to around 72% accuracy by adjusting the d parameter. The staircasing procedure adjusted the step size on a logarithmic scale (i.e., larger adjustments for higher values of d) based on the log-adaptive two-down one-up procedure outlined in Rouault et al. (2018). The d parameter for experimental blocks was fixed to the average of the smallest d value (the hardest level) that the participant achieved during the staircasing trials, and the final d value that was reached at the end of the staircasing trials.

If participants opted to see additional information on the information-seeking trials, a fixation cross was again presented for 1,000 ms followed by an easier version of the dot stimuli whereby the correct side remained the same, but the dot difference d was increased by the number of dots equal to a step size of +0.5 in log-space.

In the color discrimination task (performed for one session in Experiment 2), participants were asked to decide which of two stimuli was more red on average. Each stimulus was a multi-item display composed of eight colored shapes spaced regularly in a circle, four of which were initially masked. The mean color of all eight color points varied in red, green, and blue space between pure red ([1, 0, 0]) and pure blue ([0, 0, 1]) and was determined by C with the mean color corresponding to $[C, 0, 1 - C]$. The variance was fixed at 0.1. Stimuli were presented for 500 ms, but otherwise trial events and timings were the same as for the dots task, and the task likewise began with 100 practice trials that were used to staircase task performance to around 72% accuracy by titrating the difference in C parameters between the two stimuli. In experimental blocks, if participants chose to seek information, they would again be presented with a fixation cross followed by stimuli in which all eight color points for each stimulus were visible.

Computer-Generated Partners

In each session, participants were paired with two different virtual partners: an underconfident partner and an overconfident partner. Participants completed five blocks of 25 trials in one partner condition followed by five blocks in the other partner condition (order randomized). The first block with each partner served as a familiarization block and did not include information-seeking trials. Of the remaining 100 trials per partner condition, 32 trials (eight per 25-trial block) were randomly selected to be information-seeking trials. On each trial, the partner's probability of choosing the correct response was determined as $p(\text{correct}) \sim N(\mu = 0.8, \sigma = 0.066)$, where $0.6 \leq p(\text{correct}) \leq 1$ such that partners were slightly more accurate than participants themselves in order to account for egocentric discounting, a bias whereby one's own opinion is weighted more than someone else's opinion (Yaniv & Kleinberger, 2000). To translate the continuous $p(\text{correct})$ into a binary choice, a random number between 0 and 1 was generated for each trial. If this random number was less than $p(\text{correct})$, the partner chose the correct response; otherwise, the partner chose the incorrect response. Partners' confidence c was then computed as: $c = 50 + 50 \times (a + (p(\text{correct}) - 0.5) \times 0.8 + e)$, where $a = 0.1$ for the low-confidence partner and $a = 0.6$ for the high-confidence partner, and $e \sim N(\mu = 0, \sigma = 0.05)$. In the equation used to generate the partners' responses, confidence starts at a baseline of 50% (which signifies guessing) and can go up to 100% (representing complete certainty). This confidence is generally proportional to the objective probability of the decision being correct ($p(\text{correct})$), but the relationship is imperfect. The scaling factor 0.8 adjusts how much the confidence c changes for a unit change in $p(\text{correct})$; the value 0.8 ensures that confidence levels are sensitive to changes in accuracy while preventing excessive fluctuations or ceiling effects, particularly for the overconfident partner. The offset term a modifies the confidence

value in accordance with the overall tendency toward low or high confidence, differentiating between the underconfident and overconfident partners. Finally, e introduces further noise into the confidence reports, reflecting that confidence judgements in real life are not perfectly predictable or stable. As a result, the underconfident partner's reports were centered around 67% confidence, while the overconfident partner's reports centered around 92% confidence, creating distinct confidence profiles for each partner. By this design, the confidence of the partners genuinely correlated with their objective accuracy. This approach is crucial, given that studies have shown people to be sensitive to such alignment between confidence and accuracy (Pescetelli et al., 2021; Tenney et al., 2007).

Upon completing a set of five blocks with a particular partner, participants were asked to rate the partner's confidence, accuracy, and likeability on a 10-point Likert scale. In addition, participants were asked to indicate what gender they associated with their partner (here, only male vs. female).

Data Analysis

All analyses were conducted using R (Version 4.4.0) within RStudio (Version 2022.02.1). Preliminary checks evaluated participants' public confidence, accuracy, and information-seeking behavior across task and partner conditions. We used paired-sample t tests to compare confidence levels between correct and incorrect choices, accuracy between informational and normative task conditions, accuracy between initial and postinformation responses, and the proportion of information-seeking choices between initially correct and incorrect responses. To assess participants' metacognitive sensitivity, we employed one-sample t tests comparing the Type II area under the receiver operating characteristic curve (AUROC2) against the chance level of 0.5. Additionally, a two-way analysis of variance (ANOVA) examined the effects of task condition, partner condition, and their interaction on public confidence, followed by paired-sample t tests comparing confidence levels with overconfident and underconfident partners within each task condition. As our first key analysis, a two-way ANOVA was conducted to examine the effects of task and partner conditions on the proportion of trials where participants declined additional information (as a proxy for private confidence). Follow-up t tests were employed to further examine significant interactions between partner and task conditions. As our second key analysis, to investigate trial-wise information-seeking behavior, a logistic linear mixed-effects model was fitted using the lme4 package. The model predicted the likelihood of seeking additional information based on public confidence, task condition, partner condition, and their interaction, with random intercepts and slopes for participants. We further stratified the model by task condition to investigate how public confidence related to information seeking under the different partner conditions. Finally, we explored participants' perceptions of their partners' accuracy, confidence, likeability, and gender through separate ANOVAs, with task condition and partner condition as predictors. All tests were two-tailed.

Transparency and Openness

Data and analysis code for both experiments are available on Open Science Framework (https://osf.io/vuab7/). The experiment code is available on GitHub (https://github.com/MajaFriedemann/Normative-and-informational-confidence-matching).

Results

Before the key analyses relating to confidence matching effects, we first report basic analyses of accuracy, confidence and information-seeking choices, to establish that these were generally well-matched across task and partner conditions.

Accuracy and Confidence Calibration

In both tasks, participants' confidence reports were well aligned with their accuracy, with systematically higher confidence reports for correct compared to incorrect responses, $M = 75.2$ versus $M = 70.5$, $t(28) = 8.3$, $p < .001$ for the informational task, and $M = 77.7$ versus $M = 72.9$, $t(28) = 9.0$, $p < .001$ for the normative task in Experiment 1; $M = 76.6$ versus $M = 72.0$, $t(58) = 9.7$, $p < .001$ for the informational task and $M = 78.6$ versus $M = 73.1$, $t(58) = 10.1$, $p < .001$ for the normative task in Experiment 2. Participants performed at similar accuracy levels for initial choices in the normative and the informational task sessions, $M = 74.2 \pm 7.6$ versus $M = 73.9 \pm 6.8$, $t(28) = 0.2$, $p = .86$ for Experiment 1; $M = 74.2 \pm 7.3$ versus $M = 72.6 \pm 8.0$, $t(58) = 1.3$, $p = .18$ for Experiment 2. With first-order task performance being held constant, plotting receiver operating curves gives an indication of participants' metacognitive sensitivity (the ability to distinguish between one's own correct and incorrect first-order responses). Participants displayed varying levels of metacognitive sensitivity, echoing findings on individual differences in metacognitive abilities (Fleming et al., 2010). Despite this variability, participants' metacognitive sensitivity was, on average, above chance: Type II AUROC2 analyses revealed values significantly greater than the value of 0.5, $M = 0.66$, $t(28) = 12.2$, $p < .001$ when paired with the overconfident partner and $M = 0.66$, $t(28) = 15.8$, $p < .001$ when paired with the underconfident partner in Experiment 1; $M = 0.67$, $t(58) = 19.1$, $p < .001$ when paired with the overconfident partner and $M = 0.67$, $t(58) = 20.7$, $p < .001$ when paired with the underconfident partner in Experiment 2. There was no significant difference in AUROC2 values between partner conditions ($t < 1$ in both experiments), indicating that social context did not affect metacognitive sensitivity.

Information Seeking

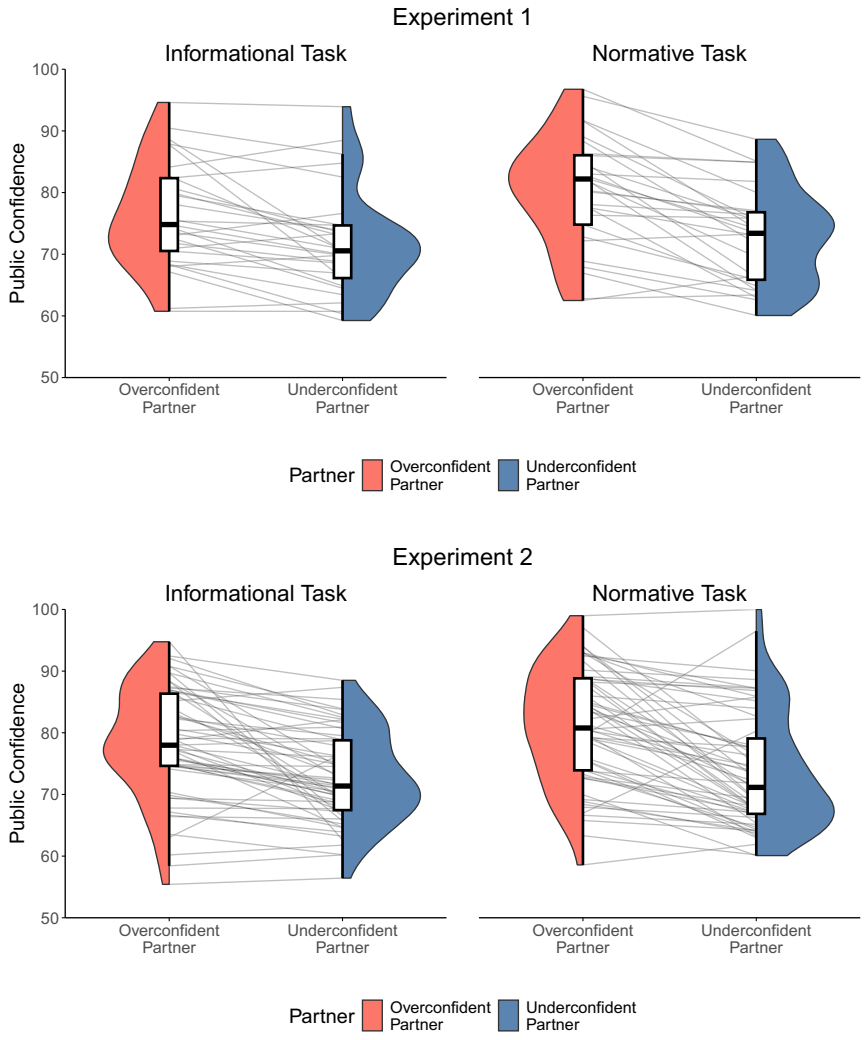
On trials in which participants did not see their partner's response but instead had the option to seek further information, participants chose to see the stimulus again in an easier version on 38.9% (Experiment 1) and 38.7% (Experiment 2) of trials. There was considerable variation between participants with information seeking ranging from 1% to 99% between participants for both experiments, as is typically observed (Desender et al., 2018; Pescetelli et al., 2021). Participants made good use of further information with accuracy increasing from 68.4% for initial choices to 87.0% for second choices, $t(28) = 7.8$, $p < .001$, for Experiment 1 and from 67.5% for initial choices to 84.5% for second choices, $t(58) = 6.8$, $p < .001$, for Experiment 2. In support of information seeking being an index of private confidence, participants sought more information on 45.5% of trials where their initial choice was incorrect compared to 36.5% of trials where their initial choice was correct in Experiment 1, $t(28) = 3.9$, $p < .001$, and 45.5% of trials where their initial choice was incorrect compared to 36.3% of trials where their initial choice was correct in Experiment 2, $t(58) = 6.8$, $p < .001$.

Confidence Matching

Despite accuracy being very similar across partner conditions, $t(28) = 1.4$, $p = .17$ for Experiment 1; $t(58) = 0.4$, $p = .71$ for Experiment 2, participants exhibited confidence matching behavior such that they reported overall higher confidence when paired with the overconfident partner and lower confidence when paired with the underconfident partner (see Figure 3). Interestingly, we see hints of a bimodal distribution in the underconfident partner condition, suggesting the presence of distinct subgroups among participants. One group appeared to maintain consistently high-confidence levels, even when paired with an underconfident partner, indicating a certain "stubbornness" in their high confidence. In contrast, only a few participants consistently exhibited low confidence across conditions. An ANOVA was conducted testing the effects of task condition (normative vs. informational) and partner condition (overconfident vs. underconfident) and their interaction. The results showed a significant effect of partner condition on participants' public confidence, $F_{\text{partner}}(1, 28) = 50.7, p < .001, F_{\text{task}}(1, 28) = 3.1$, $p = .09$, $F_{\text{Task} \times \text{Partner}}(1, 28) = 3.6$, $p = .07$ in Experiment 1; $F_{\text{partner}}(1, 58) = 65.9$, $p < .001$, $F_{\text{task}}(1, 58) = 3.8$, $p = .06$, $F_{\text{Task} \times \text{Partner}}(1, 58) = 2.3$, $p = .14$ in Experiment 2. The difference in public confidence between partner conditions was numerically larger for the normative task. In this task, participants must match confidence to maximize reward. However, a substantial difference was apparent in both the normative task: $M_{\text{shift}} = 7.4, t(28) = 6.3, p <$ .001 in Experiment 1; $M_{\text{shift}} = 7.5$, $t(58) = 6.9$, $p < .001$ in Experiment 2, and the informational task: $M_{\text{shift}} = 4.5$, $t(28) = 4.1$, $p < .001$ in Experiment 1; $M_{\text{shift}} = 5.7$, $t(58) = 6.1$, $p < .001$ in Experiment 2. These shifts in confidence were substantial, partly even exceeding those observed between objectively correct and incorrect responses ($M_{\text{shift}} = 4.7$ in Experiment 1; $M_{\text{shift}} = 5.2$ in Experiment 2).

Figure 3

Confidence in the Informational and Normative Tasks When Paired With the Underconfident and Overconfident Partner



Note. Faint lines show individual participant means. Violin and box plots show the distributions of participant means. See the online article for the color version of this figure.

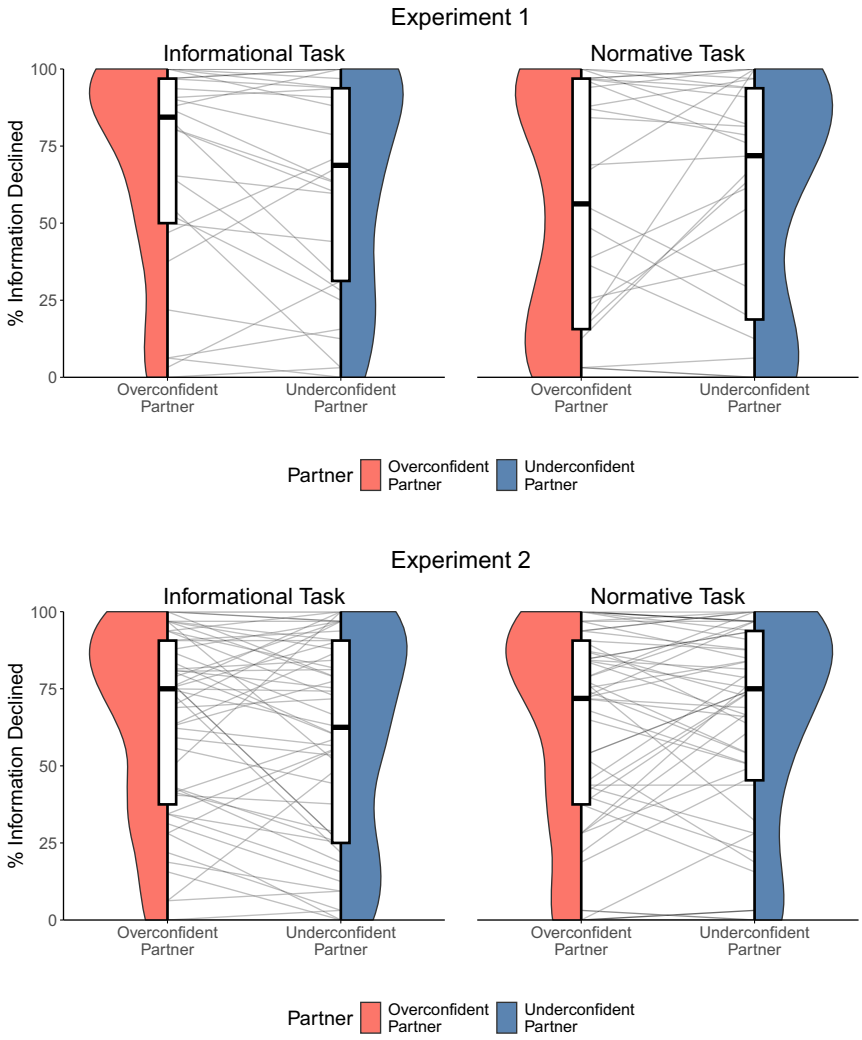
Influence of Partner Confidence and Task Type on Information Seeking

Given that confidence matching was successfully induced in both experimental contexts—that is, both with (presumed) informational and normative influence—our critical analyses concern whether the corresponding effects observed on participants' expressed confidence nevertheless mask crucial underlying differences in their private confidence. As a first test of this key hypothesis, we examined how overconfident versus underconfident partners affected participants' information-seeking choices across task conditions. The results are shown in Figure 4, which plots participants' likelihood of declining additional information as a proxy for private confidence, with a higher likelihood of declining information implying greater confidence in the initial decision. The data were analyzed in an ANOVA testing the influence of task condition and partner condition and their interaction on the proportion of trials where participants declined to seek further information. Our key prediction was that there should be a significant interaction effect between task condition and partner condition: if informational influence, but not normative influence, changes private confidence, then we should see a change in information seeking behavior between partner conditions in the informational condition only.

Indeed, this interaction was significant in Experiment 1 and trending in Experiment 2, $F_{task}(1, 28) = 2.6, p = .12, F_{partner}(1, 28) = 0.0, p = .90, F_{Task \times Partner}(1, 28) = 4.8, p < .01$ in Experiment 1; $F_{task}(1, 58) = 0.3, p = .59, F_{partner}(1, 58) = 0.5, p = .50, F_{Task \times Partner}(1, 58) = 3.1, p = .08$ in Experiment 2. Participants

Figure 4

Percentage of Information Declined in the Informational and Normative Tasks When Paired With the Underconfident and Overconfident Partner



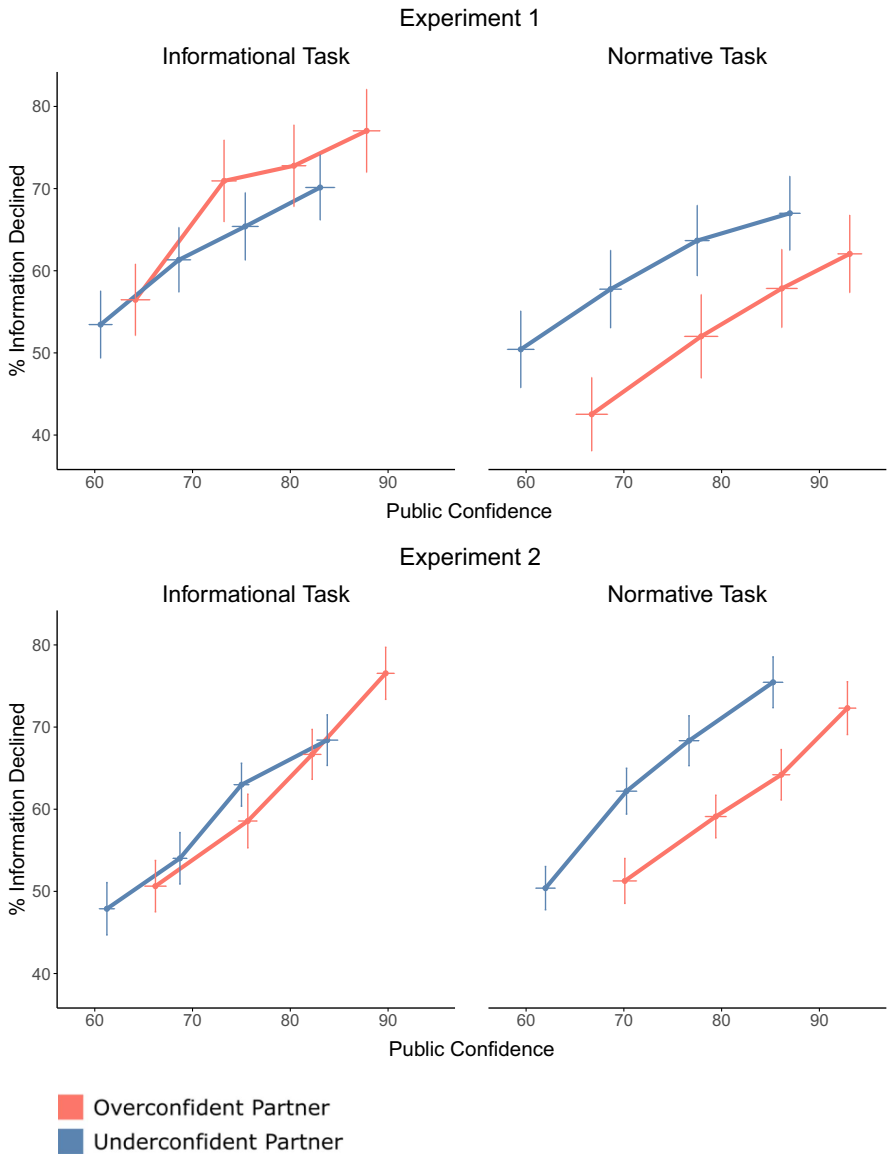
Note. Faint lines show individual participant means. Violin and box plots show the distributions of participant means. Note that we show information declined rather than information seeking because the former scales positively with private confidence: the higher the private confidence, the higher the percentage of information declined should be. See the online article for the color version of this figure.

tended to seek more information when paired with the underconfident partner compared to the overconfident partner in the informational task, $t(28) = 1.7$, $p = .09$ in Experiment 1; $t(58) = 1.7$, $p = .10$ in Experiment 2, whereas the opposite pattern was seen for the normative task, $t(28) = -1.2$, $p = .25$ in Experiment 1; $t(58) = -0.8$, $p = .41$ in Experiment 2. Thus, the change in information-seeking behavior depending on the partner's confidence bias was evident as hypothesized for the informational task. Interestingly, information seeking behavior in the normative task did not merely remain unaffected, but unexpectedly exhibited an inverse pattern compared to the informational task.

Our second key analysis focused on the relationship between public confidence and information seeking on a trial-by-trial level, evaluating whether the predicted relationship (and dissociation) between these two measures across partner conditions as depicted in Figure 1 would be observed. Aggregated results are shown in Figure 5,

Figure 5

Percentage of Information Declined as a Function of Public Confidence in the Informational and Normative Tasks When Paired With the Underconfident and Overconfident Partner

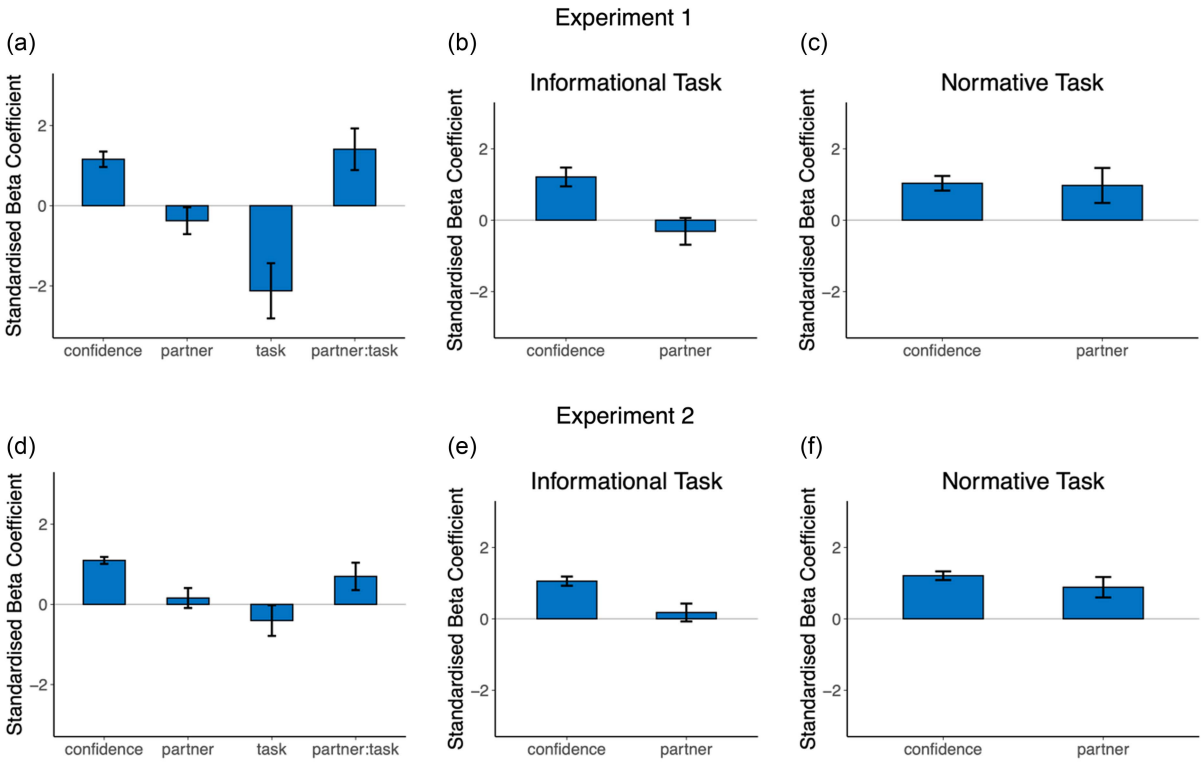


Note. For each participant, confidence was divided into quartiles and the proportion of information-seeking choices within each confidence quartile was computed. The graph displays the grand mean across participants and standard error of the mean for both public confidence and information seeking. Note that we show information declined rather than information seeking because the former scales positively with private confidence: the higher the private confidence, the higher the percentage of information declined should be. Compare to hypothesized patterns for informational and normative influence in Figure 1. See the online article for the color version of this figure.

where *y*-axis values again plot participants' likelihood of declining further information as the critical proxy for private confidence. The empirical results overall match well with the patterns predicted in Figure 1. The analysis was performed on a trial level by applying a linear mixed-effects model. Trial-wise information seeking choices were predicted in a logistic regression by public confidence in the initial decision, task condition, partner condition, and an interaction term between task and partner conditions, allowing for random intercepts and slopes by participant. There was a significant effect of confidence ($\chi^2 = 36.2, p < .001$ in Experiment 1; $\chi^2 = 160.6, p < .001$ in Experiment 2; evident in the positive slope of all lines in Figure 5, showing that as public confidence increases, the percentage of information declined also increases) as well as a significant interaction between task condition and partner condition ($\chi^2 = 7.3$, $p < .01$ in Experiment 1; $\chi^2 = 4.2$, $p < .05$ in Experiment 2) on information seeking (Figure 6a and 6d). To unpack the interaction, we next ran separate regression models per task condition, predicting information-seeking choices in a logistic regression by public confidence and partner condition, allowing for random intercepts and slopes by participant. These analyses revealed that, when controlling for confidence, there was no reliable effect of partner condition on information seeking in the informational task condition ($\chi^2 = 0.7$, $p = .40$ in Experiment 1; $\chi^2 = 0.5$, $p = .48$ in Experiment 2; evident in the consistent regression line for the blue and pink lines in the informational task in Figure 5, indicating that the relationship between public confidence and percentage of information declined remains stable across partner conditions, and in the zero β weights for partner condition in Figures 6b and 6e), whereas there was a significant effect of partner condition on information seeking in the normative task condition ($\chi^2 = 3.9, p < .05$ in Experiment 1; $\chi^2 = 9.6$, $p < .01$ in Experiment 2; evident in the divergence of the blue and pink lines in the normative task in Figure 5, showing that the relationship between public confidence and percentage of information declined varies between partner conditions, and in the positive β weights for partner condition in Figures 6c and 6f). These results are in line with our predictions. They demonstrate that public confidence drives information-seeking behavior across both task conditions, but there is an additional impact of the partner condition in the normative condition: When paired with an underconfident partner, more information is declined than would be expected based on the level of public confidence (i.e., suggesting that the private confidence is in fact higher than the publicly reported value). Conversely, when paired with an overconfident partner, less information is declined than would be expected based on the level of public confidence (i.e., suggesting

Figure 6

Beta Coefficients From Linear Mixed-Effects Models Predicting Trial-Wise Information-Seeking Choices (Where Declining Information = 1, Used as a Proxy for Private Confidence)



Note. Panels (a) and (d) display the β coefficients for the full model, including public confidence, partner condition (with underconfident partner coded as 1), task condition (with normative task coded as 1), and the interaction between partner and task conditions, for Experiment 1 and Experiment 2, respectively. Panels (b) and (e) show the β coefficients for the informational task condition with public confidence and partner condition as predictors, while Panels (c) and (f) depict the coefficients for the normative task condition. Error bars represent standard errors of the β estimates. See the online article for the color version of this figure.

that the private confidence is in fact lower than the publicly reported value).

Collectively, these findings align with key predictions, indicating the presence of distinct informational and normative impacts on private and public confidence. The ANOVA results highlight distinct partner influences on information seeking behavior between the informational and normative task conditions (albeit only significantly so in Experiment 1). The regression analysis distinctly indicates divergence between private and public confidence under normative social influences but not informational ones. In the informational task, accounting for public confidence negates any effect of partner on information-seeking behavior, as the change in information seeking between partner conditions aligns with the participant's public confidence. In contrast, in the normative task, for a given level of public confidence, participants decline more information when paired with the underconfident partner than when paired with the overconfident partner. This suggests that participants' private confidence is higher at the same public confidence level when interacting with an underconfident partner compared to an overconfident partner (Figure 5).

Order Effects

As mentioned above, a motivation for conducting Experiment 2 was the observation of order effects in Experiment 1. These effects were apparent in an ANOVA similar to the one above testing our first key prediction, but now including task order alongside task condition and partner condition as predictors of participants' information seeking. Applied to the Experiment 1 data, this analysis revealed that the significant interaction between task condition and partner condition, $F(1, 27) = 5.9$, $p < .01$, described above was qualified by a significant three-way interaction between task order, task condition, and partner condition, $F(1, 27) =$v5.1, $p < .01$. This interaction arose because the hypothesized effects were stronger for participants experiencing the informational task condition first than for participants who first completed the normative task condition (see Appendix). Our interpretation of the interaction was that experiencing the normative task condition first allows participants to develop a stable view of their own performance in the task. This is based on the trial-by-trial feedback provided in this condition. The partner's confidence therefore carries less useful information about task difficulty in the subsequent informational condition with the same task, compared to the case where the informational task condition is the one experienced first.

Thus, in Experiment 2, we introduced a second perceptual task so that, even after a session of the normative task condition, participants should begin the informational task condition without a stable evaluation of their performance in the newly introduced task. Indeed, in Experiment 2, the effects of partner condition on public confidence and information-seeking behavior between task conditions are similar across the two condition orders. This is reflected in the lack of significant three-way interaction between task order, task condition, and partner condition, $F(1, 57) = 0.2$, $p = .67$.

Partner Perception

A final set of exploratory analyses focused on participants' evaluations of the confidence, accuracy, and likeability of each partner, for which they used a 10-point Likert scale to express their explicit ratings on these dimensions after each five-block series interacting with a partner. In addition, they also identified the gender they associated with their partner. The mean ratings for these responses are summarized in Table 1. Across both experiments, participants correctly identified the overconfident partner as being more confident than the underconfident partner, $F_{task}(1, 28) = 3.9$, $p = .05$, $F_{partner}(1, 28) = 18.3$, $p < .001$, $F_{Task \times Partner}(1, 28) = 0.9$, $p = .34$ in Experiment 1; $F_{task}(1, 58) = 0.0$, $p = .96$, $F_{partner}(1, 58) = 43.0$, $p < .001$, $F_{Task \times Partner}(1, 58) = 3.8$, $p < .10$ in Experiment 2. Accuracy ratings did not significantly differ between the overconfident and underconfident partners, $F_{task}(1, 28) = 5.7$, $p < .05$, $F_{partner}(1, 28) = 0.0$, $p = .89$, $F_{Task \times Partner}(1, 28) = 0.8$, $p = .37$ in Experiment 1; $F_{task}(1, 58) = 0.0$, $p = .95$, $F_{partner}(1, 58) = 2.3$, $p = .37$, $F_{Task \times Partner}(1, 58) = 0.9$, $p = .33$ in Experiment 2. Likeability ratings also did not significantly differ between the overconfident and underconfident partners, $F_{task}(1, 28) = 3.1$, $p = .08$, $F_{partner}(1, 28) = 0.0$, $p = .85$, $F_{Task \times Partner}(1, 28) = 1.2$, $p = .28$ in Experiment 1; $F_{task}(1, 58) = 0.6$, $p = .45$, $F_{partner}(1, 58) = 0.0$, $p = .82$, $F_{Task \times Partner}(1, 58) = 1.9$, $p = .18$ in Experiment 2. Finally, participants were more likely to identify the overconfident partner as male compared to the underconfident

Table 1

Mean (± Standard Deviation) Ratings on a 10-Point Likert Scale of Perceived Confidence, Likeability, Accuracy, and Gender in Experiments 1 and 2 in the Normative and Informational Tasks for Underconfident and Overconfident Partners

	Normative task		Informational task	
Rating variable	Underconfident partner	Overconfident partner	Underconfident partner	Overconfident partner
Confidence				
1	5.7 ± 1.8	7.7 ± 1.8	4.8 ± 1.7	8.3 ± 1.6
2	5.2 ± 1.5	8.1 ± 1.7	4.6 ± 1.6	7.9 ± 1.7
Likeability				
1	6.8 ± 1.8	6.7 ± 1.6	6.1 ± 1.7	5.8 ± 1.5
2	7.0 ± 1.7	6.8 ± 1.8	6.1 ± 1.6	6.2 ± 1.4
Accuracy				
1	6.8 ± 1.6	7.2 ± 1.7	5.8 ± 1.5	5.9 ± 1.7
2	6.9 ± 1.6	7.2 ± 1.9	6.0 ± 1.5	6.1 ± 1.8
% male				
1	44.8	58.6	34.5	69.0
2	45.8	66.1	39.0	61.0

partner, $F_{task}(1, 28) = 0.1, p = .82, F_{partner}(1, 28) = 9.5, p < .01, F_{Task \times Partner}(1, 28) = 2.3, p = .13$ in Experiment 1; $F_{task}(1, 58) = 0.9, p = .34, F_{partner}(1, 58) = 9.7, p < .01, F_{Task \times Partner}(1, 58) = 0.1, p = .76$ in Experiment 2. A related study by Bang et al. (2017) involving a joint decision-making paradigm showed similar findings, whereby participants held a stereotype that highly confident partners were more likely to be identified as male and less confident partners as female. Furthermore, in their study, participants liked partners who were highly accurate yet displayed low confidence the most. However, in contrast, we found no significant influence of partners' confidence on their likeability.

Discussion

The ability to evaluate one's confidence in decisions and beliefs is a crucial aspect of adaptive behavior. Sharing these evaluations with others can enhance group decision making and improve collective performance even in the absence of feedback (Bahrami et al., 2010; Shea et al., 2014). As partners work together, their average public confidence as well as the distribution of confidence reports become increasingly alike (Bang et al., 2017; Pescetelli & Yeung, 2020, 2022). This confidence matching may be driven by an attempt to better calibrate one's own confidence judgements to the difficulty of the task, a form of informational influence (Sherif, 1935), affecting confidence at the private level. But confidence matching may also be driven by social reasons unrelated to the accuracy of confidence judgements, such as a desire to fit with observed norms, to avoid being perceived as incompetent or, critically, to promote equality in group decision making. These are all forms of normative influence (Asch, 1951), affecting confidence at the reporting level only. In two experiments, participants performed a series of perceptual decisions alongside a partner. The partner's confidence reports as well as the presence of feedback and need for joint decision making were manipulated to better understand the conditions under which social information causes confidence matching at the private or public level.

We observed confidence matching behavior consistently across our informational and normative task conditions in both experiments, with participants expressing higher average confidence in their initial decisions when paired with an overconfident partner than when paired with an underconfident partner. However, although the same public metacognitive behavior, a matching of public confidence, occurs in both cases, replicating results seen previously by Bang et al. (2017) and Pescetelli and Yeung (2020, 2022), differences in partner effects on information seeking suggest that the nature of this confidence matching differs. Taking information seeking as a behavioral marker of private confidence (Desender et al., 2018, 2019; Pescetelli et al., 2021), we observed that only in the informational task condition did participants tend to seek more information before finalizing their decisions when the participants themselves publicly expressed lower confidence (i.e., when paired with an underconfident partner). In contrast, in the normative task condition, there was a shift in public confidence reports across partner conditions without a corresponding shift in information-seeking behavior, despite a numerical trend in the opposite direction. This pattern suggests that in the normative task, people may strategically alter the mapping between their private confidence and public confidence reports based on social context (Bang et al., 2017, 2020). Consistent with this interpretation, we find a shifted relationship between participants' public confidence and their information-seeking choices when paired with different partners in the normative task. In contrast, we see no such shift in the informational task, suggesting that here participants are instead using their partner's confidence reports primarily to inform and calibrate their own private confidence (although we do not rule out the possibility that participants in this condition are also subtly influenced by normative factors, such as the desire to conform to their partner's confidence level). These findings highlight the context-sensitive influence of both normative and informational factors in shaping confidence reports as different mechanisms behind confidence matching in social contexts.

Collectively these results support the notion of confidence as a general abstract representation of an individual's likelihood of being correct, allowing for flexible and generalized metacognitive control over thought and behavior (Yeung & Summerfield, 2012). Notably, in the normative task condition, participants exhibited this flexibility by using their confidence estimates to guide information-seeking choices independent of how they mapped their confidence onto public reports based on the social context. Although these results are as predicted, it is noteworthy that they imply that participants can clearly separate their representations of confidence as they relate to different actions, that is, confidence as used to drive information seeking and confidence as used to generate a socially suitable report. This result should not be taken for granted, even given our predictions, given that other studies suggest confidence "leaks" across decisions such that confidence expressed in one task influences confidence expressed in another task (Rahnev et al., 2015). In contrast, our participants were in fact numerically less likely to seek information, indicating higher private confidence, when strategically reporting low confidence in the normative task, which is the opposite direction of effect to that expected if changes in public confidence reflected changes in private confidence.

This separation between an initial confidence computation and a subsequent context-dependent confidence report aligns with the findings of a recent functional magnetic resonance imaging study by Bang et al. (2020). This study found that the dorsal anterior cingulate cortex and perigenual anterior cingulate cortex tracked private confidence (manipulated via changes in task difficulty), whereas a context-dependent mapping to publicly public confidence (manipulated via a similar partner-confidence manipulation to that used here) was associated with activity in dorsal anterior cingulate cortex and lateral frontal pole. Along similar lines, other recent studies have found partial but not complete overlap between patterns of brain activity associated with participants' confidence reports vs their strategic adaptations related to those expressions of confidence (Boldt & Gilbert, 2022; Qiu et al., 2018). This separation may reflect the need to take into account additional factors, such as the social context, when exerting metacognitive control, over and above an initial confidence computation through a metacognitive monitoring process. These findings highlight the importance of taking into consideration the fact that confidence is used flexibly and adapting to the task at hand when studying metacognitive processes, and that the way in which confidence is probed may impact the judgment reported.

Meanwhile, the finding from the informational task condition that partner confidence affected participants' private confidence, not just how they reported their confidence, suggests that contextual factors are integrated into private feelings of confidence, rather than these merely being a read-out of the current state of evidence accumulated in the first-order decision (Boldt et al., 2017; Kiani et al., 2014;

Koriat & Levy-Sadot, 2001; Murphy et al., 2015). Taking into account a variety of contextual information that is not directly related to the task at hand, but that is known to co-vary with problem-specific evidence, can sometimes lead to mistakes and biases. However, it also enables quick decision making even when information is scarce (Gigerenzer & Todd, 1999). This notion aligns with the Bayesian inference model for meta-memory proposed by Hu et al. (2021) which provides a normative framework for the integration of such contextual cues in confidence judgements. This model posits that individuals estimate their confidence based on both their processing experiences during a task and their preexisting beliefs about their overall capabilities, suggesting that the incorporation of such cues should be seen as an adaptive feature rather than a "bug" in the system. Matching confidence judgements with another person is a simple and computationally efficient heuristic to help solve the inference problem "how well am I performing at the task?"

Although the current findings highlight the flexible use of social information in forming confidence judgements based on the context, the broader applicability of these findings warrants further exploration. A study conducted by Wittmann et al. (2016) observed a similar pattern, showing how interaction with a superior partner resulted in overestimating personal capabilities in a cooperative setting but underestimating them in a competitive one, supporting the notion of flexibility in the way in which social information may influence confidence judgements depending on the context. Further research might examine other dimensions of this flexibility. One potential area of exploration is whether the context-based effects akin to those outlined by Wittmann et al. (2016) represent genuine changes in confidence or are instead reflective of communicative adjustments. Furthermore, our research prompts additional inquiries into previous findings on how confidence judgements are affected by situational factors and individual differences, such as current mood (Koellinger & Treffers, 2015), gender (Lundeberg et al., 1994), or personality traits (Campbell et al., 2004; Pallier et al., 2002; Schaefer et al., 2004). A key question that emerges is the degree to which these results represent actual changes/differences in the private sense of confidence, versus mere alterations in the public communication of confidence.

Constraints and Generality

This study provides insights into the mechanisms of confidence matching in social contexts, focusing on the separate effects of normative and informational influences on individuals' confidence judgments. The simplicity and controlled nature of the tasks—where participants expressed confidence through a visual analogue scale and were influenced by a simulated partner—help isolate key processes that are likely to extend to a broad range of social decision-making scenarios. For example, the alignment of confidence observed in our experiments parallels similar alignment effects in verbal communication documented in other studies (e.g., Fusaroli et al., 2012). However, it is important to acknowledge limitations in our experimental design. The one-way influence setup, where the simulated partner affected the participant without any reciprocal interaction, does not fully capture the dynamics of real-world social interactions, which typically involve bidirectional influence. In addition, the absolute and relative strength of normative and informational influences will very likely vary across different tasks, social contexts, individual and cultures, variations that were not explored in this study. Despite these limitations, the general principles identified in this research, such as the integration of social information into private confidence and the context-dependent adaptation of public confidence reports, are relevant in various settings where individuals need to communicate their confidence or make decisions collectively. Future research should examine these dynamics in more complex and reciprocal social environments to better understand the generalizability and limitations of our findings across different contexts.

Conclusion

In conclusion, the present study demonstrates that confidence matching in social settings can be driven by both normative and informational factors. Confidence emerges as a flexible, context-dependent signal used to optimize behavior both at the level of individual and group decisions. The findings highlight the importance of considering the influence of social context and the flexible nature of confidence when studying metacognitive processes. The presented methods demonstrate how these influences can be experimentally induced, paving the way for future research to address how these findings may be applied to improve group decision making in real-world settings.

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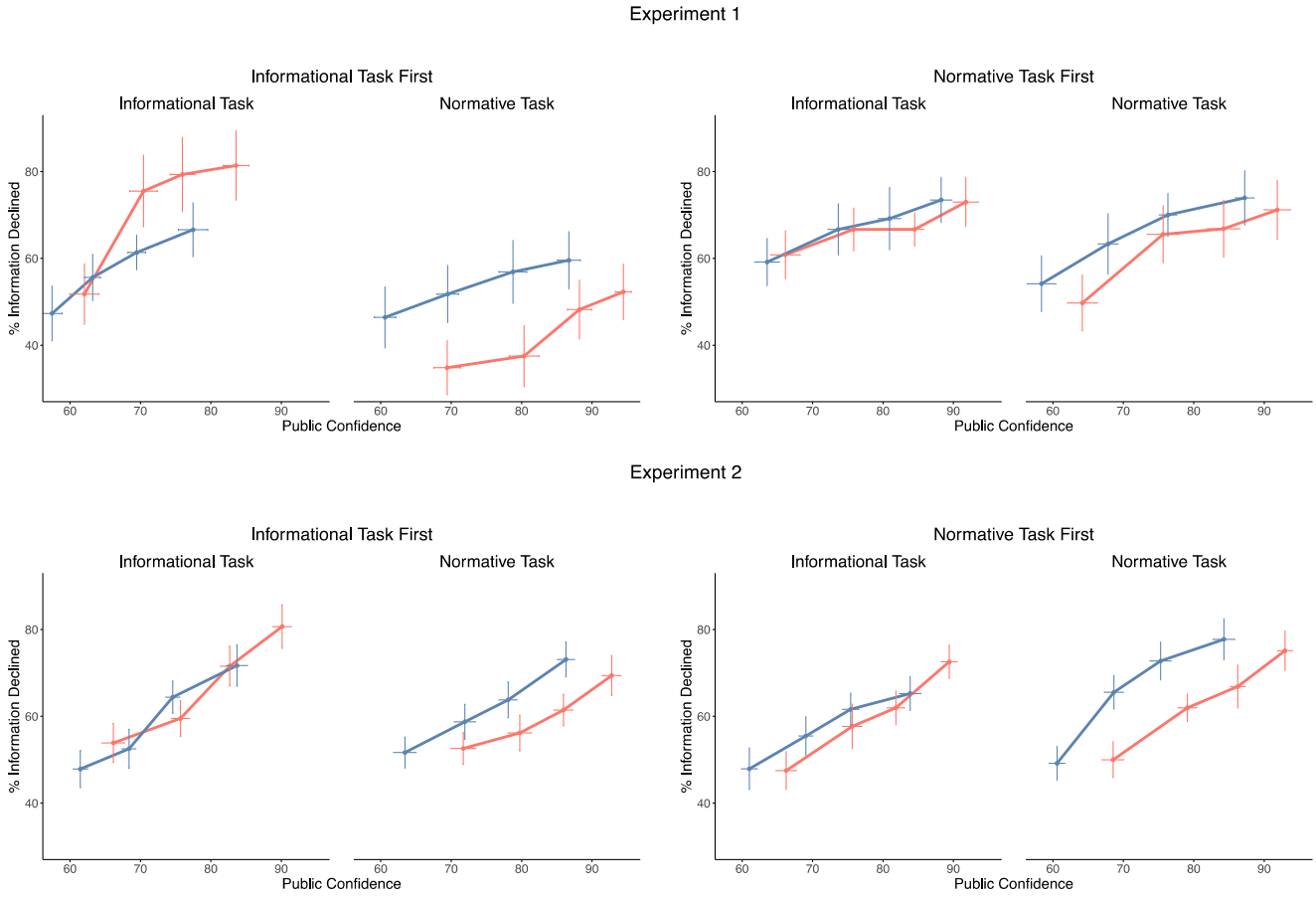
(*Appendix follows*)

Appendix

Order Effects



Note. Information seeking as a function of public confidence in the informational and normative tasks when paired with the underconfident and overconfident partner for the two task orders. For each participant, confidence was divided into quartiles and the proportion of information-seeking choices within each confidence quartile was computed. The graph displays the grand mean across participants and standard error of the mean for both public confidence and information seeking. Compare to hypothesized patterns for informational and normative influence in Figure 1. See the online article for the color version of this figure.

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