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The Heart can Lie: A Preliminary Investigation of the Role of Interoception and Theory of Mind in Deception

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Abstract

While a large part of the deception literature focuses on lying detection, the factors contributing to one's ability to lie remain unclear. The present study examined the contribution of Theory of Mind (ToM) and interoception on our ability to lie using a directed lie paradigm with two conditions ("Interrogation" and "Polygraph"), designed to enhance each of the two mechanisms. Given the relatively small sample size (n = 26 x 40 trials), special steps were taken to avoid false positives. Our results suggest that various facets of interoceptive abilities are positively related to the self-rated confidence in one's own lies, especially when under the belief that bodily signals are being monitored (i.e., in the "Polygraph" condition). Beyond providing evidence for the role of the body in lying and raising interesting questions for deception science, these results carry practical implications for criminology and lie detection protocols.

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Lying - the intentional attempt at instilling a false belief in others (Sip et al., 2012) - is a prevalent phenomenon carrying potentially important consequences. Interestingly, evidence suggests that the successful detection of a lying attempt depends more on the ability of the liar, than on the performance of the lie detector (Bond Jr & DePaulo, 2008; T. R. Levine et al., 2011; Verigin et al., 2019). However, with most of the deception literature focused on deception detection (Masip, 2017; Sternglanz et al., 2019; Viji et al., 2022), the factors contributing to one's ability to lie remain unclear. Nevertheless, some findings suggest a relationship between the propensity to tell lies, and traits that characterize the socially malevolent profile known as the Dark Triad (Paulhus & Williams, 2002), such as narcissism (Zvi & Elaad, 2018) and psychopathy (Rassin et al., 2023). While often conceptualized to be immoral and unconscionable, lying is ubiquitous in everyday life, and being able to lie skillfully can sometimes facilitate interpersonal relationships, helping us avoid conflict or causing emotional harm to others (E. E. Levine & Lupoli, 2022). In fact, recent research shows that certain forms of deception, such as prosocial lies (i.e., false statements told to benefit others, E. E. Levine & Lupoli, 2022), can increase trust (E. E. Levine & Schweitzer, 2015). Moreover, individuals who told altruistic lies were perceived as more benevolent than those who were honest (E. E. Levine & Schweitzer, 2014).

As deception requires the liar to intentionally manipulate the beliefs of others (Burgoon & Buller, 1994; Sip et al., 2012), a significant line of research has been focused on the role of theory of mind (ToM) in lying ability. ToM refers to the ability to infer that others have mental states, such as beliefs, emotions and intentions, distinct from ourselves (Baron-Cohen, 1997; Lee & Imuta, 2021; Wellman et al., 2001). The ability to tell lies, as well as their complexity, have previously been found to be related to higher ToM abilities (Evans & Lee, 2011; Talwar et al., 2007, 2017). However, studies investigating the link between ToM

and deception have predominantly been focused on children and neuroatypical individuals (Beaudoin et al., 2020; Bora & Yener, 2017; Roheger et al., 2022), and its importance in healthy adults remains to be clarified.

Besides paying attention to the person we lie to, gauging whether they believe us, some attention is also directed inwards: monitoring our own body and its reactions (e.g., cardiac activity and its related changes such as blushing), which could be used as cues to infer our real intent. This begs the question of the potential role of interoceptive abilities in deception ability. Broadly defined as one's sensitivity to their own internal signals and bodily states (Chen et al., 2021; Murphy et al., 2019; Weiss et al., 2014), Garfinkel et al. (2015) conceptualize interoception as a three-dimensional construct comprising three distinct facets, namely, interoceptive accuracy - the objective ability to monitor internal bodily signals; interoceptive sensibility - the subjective confidence in one's interoceptive accuracy; and interoceptive awareness - the metacognitive ability to correctly evaluate one's interoceptive ability. Interoception has increasingly been tied to subjective perceptual experiences (Connell et al., 2018; Seth et al., 2012), as well as individual differences in executive functions, emotional processing, and decision-making (Barrett & Simmons, 2015; Murphy et al., 2019; Petzschner et al., 2021).

Although few studies exist that investigate the relationship between interoception and deceptive ability *per se*, previous decision-making studies have demonstrated a negative correlation between interoceptive awareness and one's likelihood to make risky decisions (Dunn et al., 2010; Furman et al., 2013). This is in line with the somatic marker hypothesis, which posits that an accurate evaluation of one's bodily signals facilitates the use of such interoceptive feedback to guide rational decision making (Damasio, 1996). Indeed, Sugawara et al. (2020) further reported that individuals who received interoceptive training were more likely to show higher interoceptive accuracy and make reasoned decisions. Given that deciding to lie generally involves a consideration of the potential costs of getting caught, and

hence could also be perceived as risky behavior (Kireev et al., 2013), interoception could be construed to be negatively related to lying ability. However, some studies have instead found heightened interoceptive attention (one's self-focus towards internal bodily signals), to predict immoral behaviour, such as cheating (Ditto et al., 2006; Lenggenhager et al., 2013; Williams et al., 2016). Extending these findings to social cognition, Vabba et al. (2022) further reports individuals with lower interoception told significantly less egoistic lies when the social reputational stakes were high, whereas individuals with higher interoception did not exhibit a significant difference in the number of lies told. Given the scarce research on interoception and deception, more studies are herein needed to clarify these mixed findings.

The aim of the present study was to explore the contribution of ToM and interoception abilities on individuals' deception skills, as indicated by their lying confidence, physiological arousal and response time. To this end, we designed a directed-lying paradigm with two conditions differing in the nature of their feedback cues. The *Interrogation* condition was designed to emphasize (and preferentially mobilize) ToM-related mechanisms, whereas the *Polygraph* condition was designed to emphasize interoceptive mechanisms. In particular, we expected lying ability (i.e., higher lie confidence, shorter response time and lower physiological arousal), to be positively predicted by individuals' interoceptive abilities in the *Polygraph* condition, and by ToM skills in the *Interrogation* condition. Consistent with the cognitive load approach outlined in several theories of deception (such as the Four-Factor Theory (Riggio et al., 1987) and Activation-Decision-Construction Model (Walczyk et al., 2014)), as well as previous findings which suggest response time as a reliable cue to deception (Gonzalez-Billandon et al., 2019; Walczyk et al., 2009), we regarded shorter response times as a proxy of better lying ability.

Methods

Participants

Thirty university students from Singapore were recruited through posters, flyers, and online social media platforms, and rewarded with study credits for their time. Four participants were excluded as their data was not recorded due to technical issues. The final sample consists of 26 participants (Mean age = 20.9, SD = 2.0, range:[18, 25], Sex: 65.4% women, 34.6% men). The heart rate of one participant and response time of one participant were excluded from further analysis due to extreme outlying values. To maximize statistical power, the problematic data from these 2 participants were only excluded from analyses involving those measures; all other data were retained for analyses.

This study was approved by the NTU Institutional Review Board (NTU-IRB-2020-09-007). All participants provided their informed consent prior to participation and were awarded with academic credits upon completion of the study.

Measures

Theory of Mind (ToM). Two measures of ToM and its related constructs were administered. The Yoni Task (Shamay-Tsoory & Aharon-Peretz, 2007) is a behavioral task which assesses first and second-order ToM abilities in both cognitive and affective domains. Participants were presented with the face of a character named "Yoni", surrounded by four colored pictures of objects or faces, one in each corner of the screen. In total, each participant completed 101 trials - 49 trials assessing their affective ToM abilities, 37 trials assessing their cognitive ToM abilities and 15 control trials. During each trial, participants were instructed to respond based on specific corresponding cues such as the directions of Yoni's eye gaze, facial expressions etc., In the control trials, participants made judgements based on Yoni's physical context (physical ToM). More specifically, in first-order trials, participants were instructed to make inferences about Yoni's mental state with regards to the objects surrounding it

(e.g., "Yoni is thinking of…" for cognitive ToM trials or "Yoni likes…" for affective ToM trials). In more complex second-order trials, participants had to correctly infer the interaction between Yoni and others' mental states (e.g., "Yoni is thinking of the fruit that … wants" for cognitive ToM trials or "Yoni likes the fruit that … likes" for affective ToM trials).

The Basic Empathy Scale (BES, Jolliffe & Farrington, 2006), a 20-item self-report questionnaire measuring two dimensions of empathy, namely Cognitive ($\alpha = 0.83$) and Affective ($\alpha = 0.82$) using a 5-point Likert scale was administered. Although ToM and empathy are regarded as distinct psychological constructs, previous research findings point to them being closely related (Gallant et al., 2020; Sebastian et al., 2012). Specifically, empathy is often thought to be an integral component in the affective dimension of ToM (i.e., the ability to infer what someone else is feeling) (Shamay-Tsoory et al., 2010).

Interoception. To assess participants' interoceptive ability, participants completed a Heartbeat Counting Task (HCT, Schandry, 1981) while having their actual heartbeats recorded. During the HCT task, participants were instructed to count the number of heartbeats over 5 trials with varying time intervals (20s, 25s, 30s, 35s, 40s), the order of which was randomized. Interoceptive accuracy was computed from the difference between the estimated number and the real number of heart beats. Interoceptive sensibility was estimated as the average of the confidence ratings presented at the end of each trial. Interoceptive awareness was indexed by the correlation between the objective accuracy and the subjective confidence.

Given its multidimensional nature, the MAIA-2 (Mehling et al., 2012), a 37-item questionnaire using 5-point Likert scales was also administered. It measures eight distinct facets of interoception including Noticing (e.g., *I notice when I am uncomfortable in my body*; $\alpha = 0.70$), Not-Distracting (e.g., *I try to ignore pain*; $\alpha = 0.87$), Not-Worrying (e.g., *I can stay calm and not worry when I have feelings of discomfort or pain*; $\alpha = 0.68$), Attention Regulation (e.g., *I can refocus my attention from thinking to sensing my body*; $\alpha = 0.85$), Emotional Awareness

(e.g., *I notice how my body changes when I am angry*; $\alpha = 0.75$), Self-Regulation (e.g., *I can use my breath to reduce tension*; $\alpha = 0.62$), Body Listening (e.g., *I listen to information from my body about my emotional state*; $\alpha = 0.88$), and Trust (e.g., *I trust my body sensations*; $\alpha = 0.89$).

Deception. Using PsychoPy (Peirce et al., 2019), we implemented a directed-lying task in which participants were instructed to briefly answer 80 questions (taken from their previously taken Autobiographical Memory Questionnaire - AMQ, Rubin et al., 2003) pertaining to their personal preferences and subjective experiences, by either lying or telling the truth (depending on whether they see "lie" or "truth" written on the screen). Their goal was to make convincing answers, so that truths would be judged as truths by the receiver, and lies as lies. The nature of the receiver was different depending on the condition: participants were told that for half of the trials, they would have to convince another participant that would be observing them from a separate room (COVID regulations were used as a justification) via a webcam connection (*Interrogation* condition). For the remaining trials, participants were tasked to convince a "lie detection machine" that would be assessing their behaviour through their physiological signals (*Polygraph* condition). In reality, there was no real "receiver" and their answers were not judged externally (the study focused on their subjective ratings and reactions). The two conditions were presented in a counter-balanced order, and each comprised of 40 trials (20 truth; 20 lies).

The sequence of each trial was the same for both conditions. Participants were first instructed to respond to a question shown on a computer screen by verbally lying or telling the truth (for half of the trials in each condition, i.e., n = 20). In addition, as past studies have found associations between lying behaviour and type of question phrasing (Walczyk & Cockrell, 2022), each question was phrased either directly (e.g., "What is your favourite sport?"), or indirectly (e.g., "Is your favourite sport Hockey?") to reduce possible confounding effects. Following a short interval (0.7 - 1.5s) to allow time for response preparation, during which "Connecting..." was shown on the screen, a social or bio-feedback cue (for *Interrogation* and

Polygraph conditions respectively) was displayed for a maximum of 10s or until a response was given. Specifically, participants had to provide their answers verbally, and pressed the space key to signify the end of their response. After another short interval (1.5-2.5s), during which "Disconnecting..." was presented on the screen, participants were asked to rate their confidence in how convincing (i.e., likely to get judged as truthful) they perceived their response to be on a visual analog scale.

In the *Interrogation* condition, participants had to provide their answer while receiving social feedback in the form of a video stream of an examiner, and were informed that the examiner would be evaluating the truthfulness of their responses after observing them through the live video feed. In actuality, the displayed video feed were pre-recorded video clips of a confederate's face (staying still with minimal reactions, and with a medical mask, as the experiment was run during COVID restrictions), and the same video-clips were used with all participants. All participants reported believing that the stream was real and that the examiner was really there during the debriefing.

In the *Polygraph* condition, participants had to provide their answer while receiving bio-feedback in the form of physiological signals (including cardiac activity - ECG, respiration - RSP, and electrodermal activity - EDA), of which they were informed was live feedback of their own physiological activity. In actuality, we displayed pre-recorded video clips of a confederate's physiological signals. All participants reported believing that their own signals were shown during the debriefing.

Three outcome variables were recorded for each trial of the deception task, namely the participants' confidence ratings that their answers (lies or truths) were convincing, the response time (RT) between the question onset and the participant's key press (indicating the end of their verbal answer), and the change in heart rate associated with the response (within a window of 3.5 s).

Finally, on top of the deception task, we also measured participants' self-reported tendency to lie in their everyday life using the *Lie Scale* (Makowski, Pham, Lau, Raine, et al., 2021), a 16-item questionnaire that assesses 4 dispositional lying dimensions - Ability ($\alpha = 0.92$), Frequency ($\alpha = 0.66$), Negativity ($\alpha = 0.66$), and Contextuality ($\alpha = 0.70$).

Procedure

A within-subjects design was used in the present study, which is comprised of 2 sessions, to investigate the roles interoception and ToM play in lying ability. During session 1, participants answered a brief demographic survey as well as a questionnaire regarding their personal preferences and subjective experiences (the AMQ), followed by a series of psychological scales (i.e., BES, MAIA and Lie scale), which were randomly displayed.

During session 2, performed about one week later, the three cognitive-behavioural tasks (i.e., the deception task, HCT and the Yoni task) were administered to participants while their physiological signals (ECG, RSP, and EDA) were being recorded. The physiological recording devices were set up as follows: ECG was recorded with three electrodes placed according to a modified Lead II configuration (Takuma et al., 1995), and respiration was measured using a respiration belt. All signals were recorded at 1000Hz via the BioPac MP160 system (BioPac Systems Inc., USA).

For all participants, session 2 began with the deception task, followed by the Yoni task and the HCT, with the latter two presented in a randomized order. In the directed-lying task, items of the AMQ were presented as stimuli, with participants' recorded responses (in session 1) used to establish the ground truth.

Data Analysis

Aware of the low number of participants, we tried to take every step to 1) maximize power by using all available data (from individual trials) with appropriate statistical tools and 2)

ensure the robustness of results by cross-validating the findings across different measures and approaches.

Firstly, a manipulation check was carried out to ensure that our outcome variables were sensitive to the experimental manipulations, by testing the effect of the question phrasing (direct *vs.* indirect) and condition (polygraph *vs.* interrogation) on the outcome variables. This analysis was performed using mixed models with the participants and questions both entered as random factors. Marginal contrasts analysis (denoted by Δ) was also performed to clarify the differences between conditions. To allow for a better quantification of the uncertainty associated with the effects, as well as to increase the robustness to outliers and artefactual findings, all statistics were undertaken under the Bayesian framework (Makowski et al., 2019), using informative priors centred around 0 ($t_{Confidence}(1, 0, 1)$, $t_{RT}(1, 0, 3)$, $t_{Heartrate}(1, 0, 8)$).

To maximize the signal-to-noise ratio, we performed a feature reduction on our two groups of predictor variables (namely, ToM and interoception) using factor analysis over PCA, as the goal was to extract meaningful and consistent factors, rather than merely maximizing the variance explained. Then, we modelled the relationship between these inter-individual composite scores (note that the analysis for all individual variables is nonetheless included in the analysis report) and the three outcome variables in interaction with the condition (polygraph *vs.* interrogation). Finally, we investigated the relationship between the deception scale traits, and the ToM and interoception scores using Bayesian correlations. As all the analyses and data have been made available, we will in the manuscript focus on significant, i.e., - in this context - statistically reliable and in our opinion theoretically relevant.

The data analysis was carried out using *R 4.2* (R Core Team, 2022), *brms* (Bürkner, 2017), and the *easystats* collection of packages (Lüdecke et al., 2019, 2021; Makowski et al., 2019, 2020), and the physiological signal processing was done using the default routines available in *NeuroKit2* (Makowski, Pham, Lau, Brammer, et al., 2021). Note that EDA was not further analyzed as most participants did not yield any skin conductance responses - which we believe

was partly caused by the low temperature (with dry air-con air) of the experimental room.

The analysis was not pre-registered (stemming from an undergraduate's final year project), but the full reproducible analysis script, statistical results report, and data, are available at [**masked for blinding**]

Results

Manipulation Check

Compared to truths, lies were rated with less confidence ($\Delta = -1.35$, 95% CI $[-1.46, -1.23]$, $pd =$ 100%), but no significant difference between the conditions was found. On the other hand, the RT did not differ between truths and lies, but was significantly slower in the polygraph condition for both conditions ($\Delta = 0.25$, 95% CI [0.62, 0.41], pd = 100%). The heart rate was significantly more elevated during lies as compared to truths ($\Delta = 1.16$, 95% CI [0.57, 1.73], pd = 100%), and during interrogation as compared to the polygraph condition ($\Delta = 4.84$, 95% CI [4.23, 5.44], pd = 100%).

The indirect phrasing of the question only had a significant effect on RT ($\beta = 0.36$, 95% CI [0.21, 0.51], pd = 100%), leading to slower answers, regardless of whether they were lies or truths. Given this absence of interaction with the type of answers in any modality, this factor was not included in subsequent analysis.

Feature Reduction

The three Yoni-task dimensions and the two BES traits were combined into a unique factor, labelled *ToM* (explaining 35.76% of variance). It was loaded by the cognitive (.89), affective (.77), physical (.45) Yoni dimensions, and the affective (.41) and cognitive (.17) facets of the BES.

The eight MAIA dimensions and the three HCT components were reduced to 4 factors (explaining 65.17% of variance). The first factor, labelled *Interoception - Meta* (23.59%), was

loaded primarily by Attention Regulation (.97), Self-regulation (.63), Emotional awareness (.60), and Noticing (.49) dimensions of the MAIA and the HCT confidence score (.40). The second factor, labelled *Interoception - Listening* (18.54%), was primarily loaded by the Body Listening (.92) and Trusting (.53) MAIA dimensions, and the Awareness (-.60) and Confidence (.46) HCT scores. The third factor, labelled *Interoception - Focus* (12.07%), was primarily loaded by MAIA Not-Distracting (.87), Emotional Awareness (-.40) and HCT Accuracy (.33). The fourth factor, labelled *Interoception - Regulation* (10.97%), was primarily loaded by MAIA not-worrying (.71), HCT Accuracy (.61) and MAIA Trusting (.40).

Theory of Mind

The higher composite *ToM* score was significantly associated with a decreased confidence in lies ($\beta = -0.19$, 95% CI [-0.36, -0.02], pd = 98.47%), specifically in the polygraph condition. **Figure 1** illustrates the interindividual correlates of lying confidence. The higher composite *ToM* score was also associated with slower answers for lies ($\beta = 0.42$, 95% CI [0.01, 0.83], pd = 97.67%), specifically in the polygraph condition. No significant effect was found with regards to dispositional lying traits, heart rate, and RT for truths in both polygraph and interrogation conditions.

Interoception

The higher *Meta* interoception score was significantly associated with an increased confidence in lies, specifically in the polygraph condition ($\beta = 0.20,\ 95\%\ CI\ [0.03, 0.35],\ pd = 98.98\%$). It was also associated with faster answers for both lies ($\beta = -0.54,\ 95\%\ CI\ [-0.93, -0.15],\ pd = 99.67\%$) and truths ($\beta = -0.29,\ 95\%\ CI\ [-0.63, 0.03],\ pd = 96.10\%$), specifically in the polygraph condition. No significant association was found with regards to dispositional lying traits and heart rate in both conditions.

The higher *Listening* interoception score was significantly associated with an increased confidence in lies, in both the polygraph ($\beta = 0.43,\ 95\%\ CI\ [0.27, 0.59],\ pd = 100\%$) and

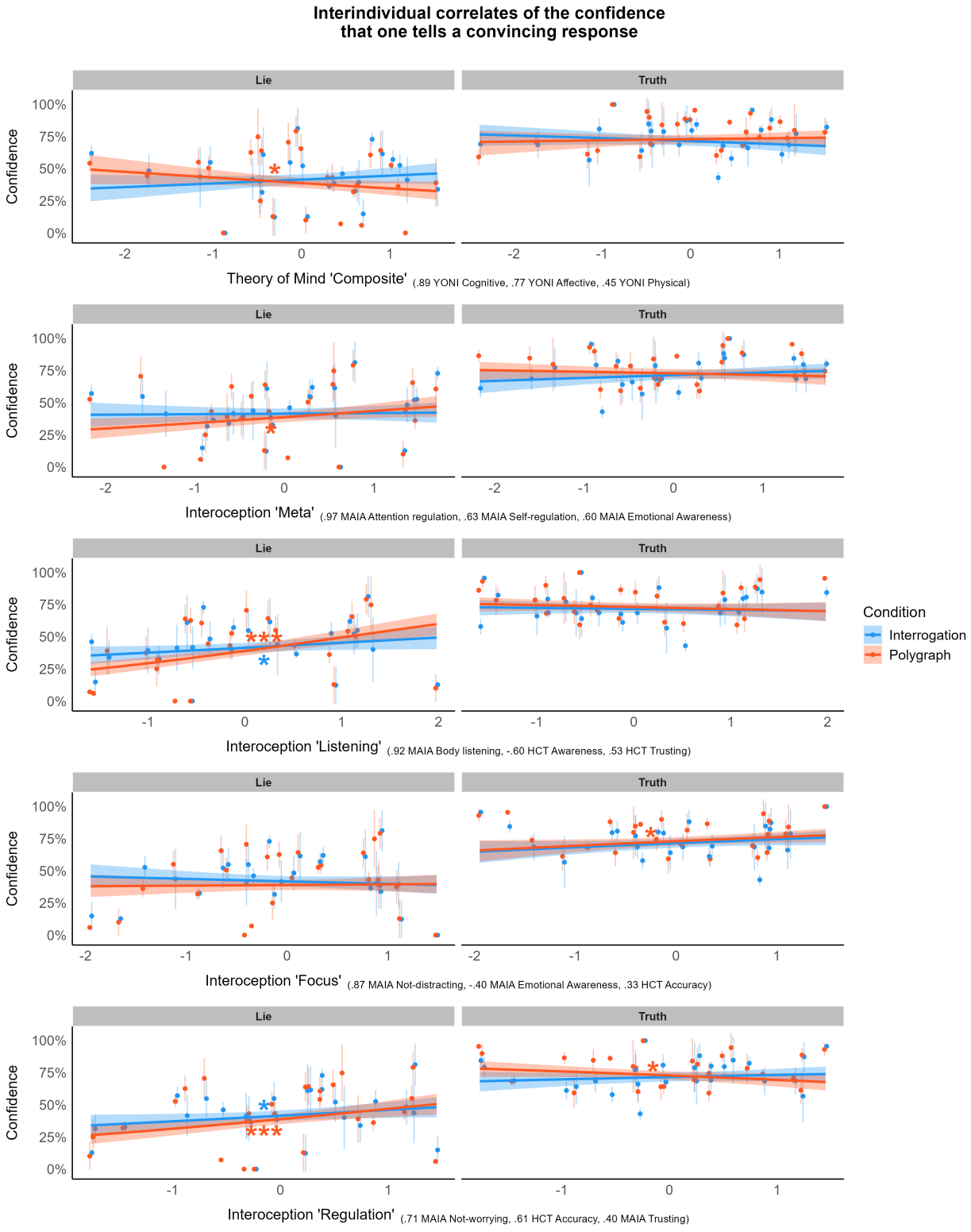

Figure 1. Interindividual corrrelates of lying confidence. The lines shows the relationship (with 95% CI uncertainty), assessed via Bayesian mixed models (**pd > 97%, **pd > 99%, ***pd > 99.9%), between the participants' interoceptive and ToM composite scores and the confidence ratings of their responses. Average lying confidence (+/- 1 SD) within the two experimental conditions is displayed as points for descriptive purposes as the models were ran on individual

interrogation conditions ($\beta = 0.16,\ 95\%\ CI\ [0.01, 0.32],\ pd = 98.04\%$). It was also associated with faster answers for both lies ($\beta = -0.42,\ 95\%\ CI\ [-0.82, -0.03],\ pd = 98.19\%$) and truths ($\beta = -0.36,\ 95\%\ CI\ [-0.76, 0.03],\ pd = 96.49\%$), specifically in the polygraph condition. The *Listening* interoception score was also positively correlated with the dispositional lying *Contextuality* trait ($r = 0.50,\ 95\%\ CI\ [0.04, 0.64],\ BF_{10} = 3.48\%$). No significant association was found with heart rate in both conditions.

The higher *Focus* interoception score was significantly associated with an increased confidence in truths in the polygraph ($\beta = 0.17,\ 95\%\ CI\ [-0.01, 0.34],\ pd = 97.16\%$); a consistent pattern, although non-significant, was found for confidence in truth in the interrogation conditions ($\beta = 0.15,\ 95\%\ CI\ [-0.02, 0.32],\ pd = 95.76\%$). The *Focus* interoception score was also positively correlated with the dispositional lying *Ability* trait ($r = 0.50,\ 95\%\ CI\ [0.22, 0.74],\ BF_{10} = 34.37\%$). No significant association was found with RT for lies and heart rate in both conditions

The higher *Regulation* interoception score was significantly associated with an increased confidence in lies in both the polygraph ($\beta = 0.32,\ 95\%\ CI\ [0.14, 0.51],\ pd = 99.99\%$) and the interrogation conditions ($\beta = 0.18,\ 95\%\ CI\ [0.00, 0.36],\ pd = 97.42\%$), and with a decreased confidence in truth only in the polygraph condition ($\beta = -0.1,\ 95\%\ CI\ [-0.36, 0.01],\ pd = 97.16\%$). No significant association was found with RT and heart rate in both conditions (**Figure 2**).

Discussion

The present study examined the contribution of ToM and interoception on our ability to lie using a directed lie paradigm with two conditions ("Interrogation" and "Polygraph") designed to enhance each of the two mechanisms. Interestingly, we found that when participants' responses were perceived to be evaluated by a person (the interrogation condition), instead of the lie detection machine (the polygraph condition), their response time for both lies and

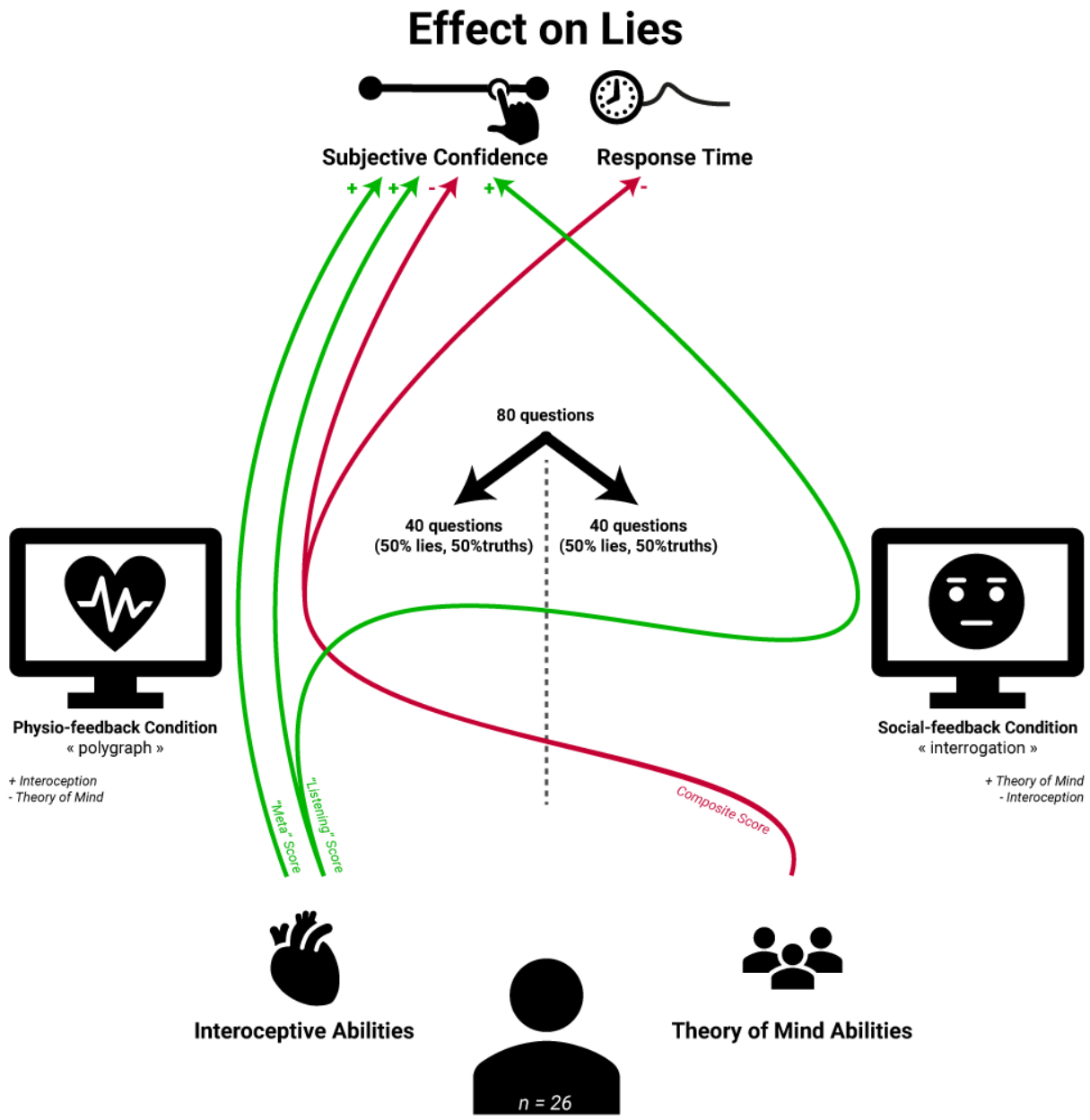

Figure 2. Summary of findings showing the positive (green) and negative (red) associations between interoception and theory of mind abilities and deception skills, depending on the experimental condition. It highlights that ToM was related to less confident and slower lies in the polygraph condition, and that specific interoceptive dimensions were related to more confident lies.

truths were faster, and their heart rate was elevated. Although the condition did not impact the subjective confidence that participants had in their answers, the pattern of results suggests that believing one's response is being evaluated by a person, instead of a machine, could induce more fear, consequently speeding up the response and increasing the physiological arousal (Aylward et al., 2017). Alternatively, the slower response in the polygraph condition could be explained by the established attentional switching hypothesis, which posits that an increase in attention towards internal signals and managing one's emotional reaction would confer less cognitive resources available, thereby resulting in individuals taking a longer time to respond (Arnold et al., 2019; Hanania & Smith, 2010). While the impacts of external settings on individuals' responses warrant further investigation, the results highlight how physiological responses can be easily confounded by other factors, independent of whether one is lying or telling the truth. For instance, the presence or absence of the "interrogator", or the saliency of the moral nature of the task (e.g. Peleg et al., 2019, argues that the polygraph test alone also acts as a "moral reminder," framing the possibility that physiological arousal in a polygraph context might be partially a reflection of individuals' attention directed to their own moral standards). By extension, our study concurs with the controversial discourse surrounding the use of physiological measures in deception research (Oviatt et al., 2018; Rosky, 2013).

Furthermore, our results suggest that higher ToM abilities were related to slower and less confident lies, but only in the polygraph condition. While previous bodies of work have reported mixed findings regarding the association between interoception and ToM (Chiou & Lee, 2013; Gendolla & Wicklund, 2009; Scaffidi Abbate et al., 2016; Wundrack & Specht, 2023), our results suggest the two are negatively linked. One possible interpretation of our findings is that people with stronger ToM abilities by default rely more on their social skills and altercentric inference when lying (i.e., they focus on - and try to read - the other person). When that mechanism is unavailable or unsuited (e.g., when there is no person to lie to - but a "machine" in our case), their corresponding lying ability decreases. However, in light of

the current field of mixed findings relating interoception and ToM (Canino et al., 2022; Gao et al., 2019; Miller, 2015; Shah et al., 2017), future studies are necessary to investigate the interaction of these mechanisms in different social contexts.

We also found that interoceptive abilities (as indicated by the composite interoception scores) are correlated with a higher confidence in one's lies in the polygraph condition, a condition in which the attention towards internal reactions is fostered. Indeed, this is in line with previous studies that found individuals with low interoception were more averse to risk when reputational stakes were high, telling fewer egoistical lies (Vabba et al., 2022). In fact, Vabba et al. (2022) further reported that people with high interoception abilities were less likely to differ in risk-taking tendencies, telling the same number of lies regardless of the social stakes. Consistent with our results, Mohr et al. (2023) found that individuals with high interoceptive accuracy were more likely to make egocentric decisions. However, in contrast to previous studies (Füstös et al., 2013; Owens et al., 2018; Pinna & Edwards, 2020; Pollatos et al., 2007), we did not find any significant relationship between individuals' interoception scores and their heart rate changes during their answers. This points toward a predominantly meta-cognitive effect without necessarily an actual bodily regulation (i.e., participants with good interoception feel that their lies are more convincing, but do not actively attenuate their bodily reactions).

Another possibility that should be tested in the future is that of a mediating role of executive functions, given their association with lying (Abe et al., 2007; e.g., Battista et al., 2021) and interoception (Molnar-Szakacs & Uddin, 2022). For instance, neuroscientific findings investigating the correlates of interoception have underlined the potential role of the anterior cingulate cortex (ACC) and anterior insula (AI) (Craig, 2009; Critchley et al., 2004; Khalsa et al., 2009; Wang et al., 2019), both of which are often thought to be activated during deception (Abe, 2011; Baumgartner et al., 2013; Sip et al., 2008), and have been implicated in cognitive processes associated with deception (such as cognitive control, Molnar-Szakacs

& Uddin, 2022; or conflict detection, Kerns et al., 2004). It is thus possible that the positive relationship between interoceptive abilities and deception is at least partially mediated by cognitive control abilities.

Although yielding promising results, the sample size of this exploratory study is a source of concern. Although we tried to mitigate it by 1) extracting more robust variables (by combining multiple ones by means of feature reduction) and 2) using a suited analysis approach (Bayesian statistics with informative priors), future replication studies with larger samples are warranted to confirm this first investigation. Nonetheless, we believe our results to be credible as we find consistent patterns across various facets and measures (for instance, all interoceptive dimensions, although distinct, share a similar trend) in line with theoretical expectations. The statistical power could also explain the overall lack of results found in relation to heart rate, which has a higher signal-to-noise ratio as compared to subjective reports (such as confidence scales). Additionally, one has to note that the participants did not have strong incentive for lying (there was no risk of losing the "reward" - i.e., student credits), which might have further decreased the potential effect sizes.

Another aspect to note is the strong reliance on self-reported measures as outcome variables of lie ability (in particular, the measure of answer confidence, but also the auto-questionnaires). This might conflate meta-cognitive abilities as well as dishonest answers. Although we tried to include more objective measures, such as RT (although it too was tied to the participants' conscious decision to press a key) and heart rate, future studies should attempt at measuring objectively the answer (lie or truth) quality, for instance by means of external examiners. Note that this is not a limitation *per se*, as it answers a slightly different question - what are the correlates of *objective* lying skills - rather than of deception self-confidence.

Additionally to the limitations pertaining to the measure of lying ability, some also concern the measure of the predictor constructs, namely ToM and interoception. While we tried to include a behavioral task as well as a subjective questionnaire for each, it has to be underlined

that they are notoriously difficult concepts to measure. In particular, objective interoceptive accuracy was assessed using the Heartbeat Counting Task (HCT). While the HCT used to be considered as a gold standard and remains one of the most commonly used measures (Desmedt et al., 2022), concerns regarding its validity have been increasingly highlighted in several studies as more research efforts are invested into developing novel interoception tasks (Brener & Ring, 2016; Desmedt et al., 2018, 2022; Legrand et al., 2022; Plans et al., 2021; Ponzo et al., 2021). Future works should further examine the relationship between interoception and lying ability using measures with better psychometric properties.

Moreover, although the cognitive and affective components of ToM and empathy share overlaps in the current literature, and there is no consensus regarding how the two concepts should be delineated, recent evidence nonetheless suggests ToM and empathy are necessarily distinct constructs with separable underlying mechanisms (Kanske et al., 2015). As such, future studies are warranted to further investigate the associations between ToM and lying ability using validated instruments sensitive to measuring ToM (such as the Theory of Mind Inventory, Hutchins et al., 2021). Furthermore, our application of feature reduction as a noise-elimination measure could have over-simplified the data. A more complex pattern of relationships, with different contributions of various subdimensions of ToM and interoception, could emerge with sufficient statistical power and valid measures.

Finally, there has been some research in the extant literature linking individual differences in ToM and interoception, as well as their neurophysiological underpinnings (Gao et al., 2019; Ondobaka et al., 2017; Shah et al., 2017). As such, it remains a possibility that the two constructs interact in influencing lying ability. However, much of this research seems focused on emotion processing, which only constitutes one of the hosts of cognitive processes required to engage in deceptive behaviour (e.g., Shah et al., 2017). Furthermore, given the overlaps in the literature surrounding ToM and empathy, it remains unclear whether interoception works with ToM or empathy (specifically affectivce empathy) in the processing of emotions.

Considering the current gaps in literature, the present study investigates the influence of individual differences in ToM and interoception on lying ability separately; this could be a useful first approach to delineate potential "main effects" of these processes. Nevertheless, future studies (with a different design and a larger sample) could investigate the interaction (and possible mediation effects) between interoception and ToM by means of, for instance, structural equation modelling.

In conclusion, this study is a first step towards assessing the contribution of ToM and interoception abilities in deception, particularly in one's ability to lie convincingly. To this end, we introduced a new paradigm to delineate the contribution of these mechanisms while remaining relevant to applied fields of lie detection and criminology (in which the experimental conditions find echoing practices). Notably, our results provide some evidence that interoception could be an important - and overlooked - process involved in deception. Furthermore, our findings extend and offer an alternate perspective to the debatable use of polygraphs, suggesting that its utility for lie detection is not only questionable, but could potentially selectively modulate deceptive skills depending on the cognitive and interoceptive profile of the participant.

Data Availability

The material (stimuli generation code, experiment code, raw data, analysis script with complementary figures and analyses, etc.) for this research is available at [**masked for blinding**].

Conflict of Interest Statement

The authors declare no conflict of interest.

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The Heart can Lie: A Preliminary Investigation of the Role of Interoception and Theory of Mind in Deception

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The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Dear Editor,

We are pleased to submit to *Current Psychology* our manuscript entitled "**The Heart can Lie: The Role of Interoception and Theory of Mind in Deception**", that builds on our previous paper published in the same journal (*The structure of deception: Validation of the lying profile questionnaire*). We believe it has the potential to attract a wide readership of scientists of various fields (embodied cognition, social psychology, criminology), and open new avenues of research.

This exploratory study validates a new paradigm to isolate and target the role of embodied and social processes (interoception and theory of mind) in deception, and importantly reports the existence of a relationship between interoceptive abilities and lying self-perceived proficiency.

The main limitation of this study is the relatively low number of participants. However, having taken all the necessary steps to ensure that the results are not false positives (using data from all individual trials, using robust statistics, cross-validated across different measures, and having high thresholds for "significance"), we are confident that the findings we discuss are meaningful. As collecting more is unfortunately rendered impossible due to financial and administrative reasons (the first author has moved to a different institution), we also fully acknowledge the limitations by explicitly discussing them and making the whole process (data + analysis) available for verification and replication purposes.

Deception being predominantly studied with a focus on its detection, this study highlights the role of bodily processes in the formation and evaluation of lies and provides the first – to our knowledge –set of data, in open-access. Beyond raising interesting questions for deception science, and validating a new paradigm for future studies to build on, it also carries practical implications for criminology, shedding new light on the mechanisms involved during lie detection protocols.

In line with our aim to set the highest standards of methodological rigour and reproducibility, all the materials (the raw data, the pre-processing script, and the analysis scrip containing additional analyses and the code to generate the figures) has been made **fully available in open-access** at https://github.com/DominiqueMakowski/DeceptionInteroTom.

This manuscript is original, not previously published, and not under concurrent consideration elsewhere. The data were collected in a manner consistent with ethical standards for the treatment of human subjects (NTU IRB-2022-187), and informed consent was obtained after the nature and possible consequences of the studies were explained. There is no conflict of interest to disclose. All authors have approved the manuscript and agree with its submission.

On behalf of all the authors,

Dominique Makowski

dom.makowski@gmail.com

Potential reviewers:

- **Dr Christopher A. Gunderson**, expert in deception, chris.gunderson@du.edu
- **Dr Leanne ten Brinke**, expert in deception, leanne.tenbrinke@ubc.ca
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Dr. Shelia M Kennison
Oklahoma State University,
Section Editor, Current Psychology

Dear Dr. Kennison,

Please find attached a revision of our manuscript submitted for your consideration to publish in the *Current Psychology*, titled 'The Heart Can Lie: A Preliminary Investigation of the Role of Interoception and Theory of Mind in Deception' (Manuscript No. CUPS-D-23-02404R1). We would also like to sincerely apologize and seek your understanding for the delay in the revision of the manuscript, which was caused by unfortunate circumstances.

We are very grateful for the constructive and encouraging feedback provided by all the reviewers and would like to extend our gratitude to you and the editorial team for coordinating this review process. In your decision letter, you mentioned:

> "*Based on the advice received, I have decided that your manuscript may be considered further after you have carried out the minor revisions as suggested by the Reviewer(s) and Associate Editor*."

We have worked on addressing the concerns raised by the reviewers in this second revision. In particular:

> Reviewer #1: "*I would like to thank the authors for addressing my comments. In my opinion, this is a nice first study into an interesting area and idea, which warrants publication and follow-up research. […]. While I believe this manuscript warrants publication, there are some aspects that could improve it, mainly making it easier for the reader to follow*."

Reviewer #1 had made a few important suggestions to improve the clarity and the flow of the Results and Discussion which we addressed accordingly. We also revised Figure 1 to accurately reflect the results and incorporated as many changes as possible in response to other comments about the use of language.

> Reviewer #2: "*I thank the author for incorporating my suggestions and comments in this revised version of the manuscript which I think is very much improved. I do not have additional comments, but I would like to better take into account a couple of my prior remarks.*"

Reviewer #2 had suggested adding a few of our replies in the previous review to the manuscript which we had done so accordingly. In particular, we have added a footnote to highlight the methodological limitation of the study due to it being an Honour's Thesis Project. We also incorporated the suggested references and discussion points to improve the manuscript further.

In our response letter below, we included more detailed responses and point-by-point changes we have made to the manuscript in response to the reviewers' comments.

We look forward to hearing your feedback on the revised manuscript.

On behalf of all the authors,

Dominique Makowski

REVISION

Reviewer #1

I would like to thank the authors for addressing my comments. In my opinion, this is a nice first study into an interesting area and idea, which warrants publication and follow-up research. It is also an involved study: getting participants to a lab for two sessions, connecting them to several pieces of equipment, and all that during a time with COVID restrictions. I also would like to thank you for your openness and transparency regarding the sub-optimal sample size and lack of preregistration.

While I believe this manuscript warrants publication, there are some aspects that could improve it, mainly making it easier for the reader to follow.

We would like to thank the reviewer for reviewing the revised submission and for providing detailed comments in both rounds of review.

MAJOR suggestions:
I would consider reframing the results around your outcome variables, rather than the two predictor variables (ToM and interoception). In the end, you want to explain the outcome variables, so it makes sense to discuss them as a paragraph on confidence in giving a convincing response, reaction times, heart rate, and potentially dispositional lying. It also aligns more with the figures. I think it would make it easier to see, at a glance, that e.g., confidence is predicted by several indicators, while heart rate is not.

We thank the reviewer for the suggestion to improve the clarify of the results section. As our hypotheses are anchored in the contribution of *ToM* and *interception* abilities on deception skills, we believe that discussing each mechanism separately would maintain the originally intended focus of this paper and be in line with the introduction.

Nevertheless, we do agree that the clarity of the results section can be further improved. We will restructure this section according to your suggestion below.

*** The discussion starts with "[…] when participants were presented with (fake) physiological feedback (the polygraph condition), instead of a face of a person they had to lie to (the interrogation condition), their response time for both lies and truths increased, as did their heart rate." Yet, for heart rate, the results state: "The heart rate was significantly more elevated during lies as compared to truth […], and during interrogation as compared to the polygraph condition […]." So, this seems contradictory: did heart rate increase in the polygraph condition (as the discussion suggests) or in

the interrogation condition (as the results suggest)? Was there a difference between lies and truths (as the results suggest) or not (as the discussion suggests)?

We thank the reviewer for pointing out the misconstruction in the discussion. After reviewing the manuscript and the analysis code thoroughly in this revision, we confirm that the results reported are according to the analysis results. Specifically, "The heart rate was significantly more elevated during lies as compared to truths (Δ = 1.16, 95% CI [0.57, 1.73], pd = 100%), and during interrogation as compared to the polygraph condition (Δ = 4.84, 95% CI [4.23, 5.44], pd = 100%)."

We have rephrased the wording in the discussion to align the interpretation with the results. Specifically, we have added the following (lines 316-327):

"…we found that when participants' responses were perceived to be evaluated by a person (the interrogation condition), instead of a lie detection machine (the polygraph condition), their response time for both lies and truths were faster, and their heart rate was elevated. Although the condition did not impact the subjective confidence that participants had in their answers, the pattern of results suggests that believing one's response is being evaluated by a person, instead of a machine, could induce more fear, consequently speeding up the response and increasing the physiological arousal (Aylward et al., 2017). Alternatively, the slower response in the polygraph condition could be explained by the established attentional switching hypothesis, which posits that an increase in attention towards internal signals and managing one's emotional reaction would confer less cognitive resources available, thereby resulting in individuals taking a longer time to respond (Arnold et al., 2019; Hanania et al., 2010)."

MINOR suggestions:

** (If the MAJOR change to the results is not made) In the results, ensure that each paragraph consistently covers all variables of interest. Now, some paragraphs do state that there were no associations with heart rate, reaction times, and/or dispositional lying traits, but other paragraphs do not specify one of those variables. I can only assume that it means they were not significant either, but it might be good to consistently mention all variables.

Thank you for providing an alternative suggestion. We have worked on the results section to (1) improve the consistency in the presentation of the data and (2) ensure that all associations, significant or not, were mentioned.

** A bit later in the discussion, p. 19, lines 46-51, it is stated that the study adds to the "discourse surrounding the use of physiological measures in past deception research, further questioning its validity as an indicator of deception". Yet, what comes before this sentence suggests that physiological measures (suggestive of a polygraph) reduce lying; it's not so much about the validity

as an indicator of deception. This also seems to contradict a later point that the present study was not about objective lying.

We agree with the reviewer that the two sentences could be better rephrased to improve the flow of the discussion. At the same time, we addressed a point made by Reviewer 2 to elaborate more on the limitation of physiological measures in deception research. We have revised the discussion to first discuss the impact of the conditions on individuals' responses, specifically on their reaction time and heart rate. We then use these results to highlight how physiological responses can be confounded by external factors, independent of whether one is lying or telling the truth, and by extension, the results add to the ongoing discourse surrounding the use of physiological measures in deception studies. Specifically, we added the following to the manuscript (lines 327-336):

"While the impacts of external settings on individuals' responses warrant further investigation, the results highlight how physiological responses can be easily confounded by other factors, independent of whether one is lying or telling the truth. For instance, the presence or absence of the "interrogator", or the saliency of the moral nature of the task (e.g. Peleg et al., 2019, argues that the polygraph test alone also acts as a "moral reminder", framing the possibility that physiological arousal in a polygraph context might be partially a reflection of individuals' attention directed to their own moral standards). By extension, our study concurs with the controversial discourse surrounding the use of physiological measures in deception research (Rosky et al., 2013; Oviatt et al., 2018)."

** In the second part of the discussion, different references for the mixed findings regarding interoception and ToM are presented on pp. 19-20, lines 60-4 and p. 20, lines 19-21. Is there a reason for this? Could the repetition of the statement be avoided, and all necessary references be included in one citation?

Thank you for this suggestion. We have combined the sentences and references so that it reads more concisely as follows (lines 400-404):

"While the HCT used to be considered as a gold standard and remains one of the most commonly used measures (Desmedt et al., 2022), concerns regarding its validity have been increasingly highlighted in several studies as more research efforts are invested into developing novel interoception tasks (Brener & Ring, 2016; Desmedt et al., 2018, 2022; Legrand et al., 2022; Plans et al., 2021; Ponzo et al., 2021)"

** In the methods, when describing the Yoni task, could you clarify the difference in trials assessing affective and cognitive ToM abilities? Perhaps an example is enough.

We have added examples to illustrate the difference between the cognitive ToM and affective ToM trials. In lines 115 to 120:

“More specifically, in first-order trials, participants were instructed to make inferences about Yoni's mental state with regards to the objects surrounding it (e.g., "Yoni is thinking of..." for cognitive ToM trials or "Yoni likes..." for affective ToM trials). In more complex second-order trials, participants had to correctly infer the interaction between Yoni and others' mental states (e.g., "Yoni is thinking of the fruit that ... wants" for cognitive ToM trials or "Yoni likes the fruit that ... likes" for affective ToM trials).”

** A few notes about Figure 1:

* Would a similar figure regarding reaction times be useful?

The figure being already quite “heavy” and complex, we are worried it might add too much weight to the manuscript to add another similar figure. Since the confidence results are the more robust and clear, we believe it is preferential to keep it as the sole illustration – though we would be happy to add a similar one for RTs if the reviewer or editor thinks it will clarify rather than blur the paper’s main take away points.

* The description "confidence that one tells a convincing lie" or "lying confidence" does not hold for the truths on the right-hand side. Why not something like "confidence that one gives a convincing response"?

We have changed the figure accordingly.

* The results state "The Focus interoception score was significantly associated with an increased confidence in truthful responses in both the polygraph", but I don't see this asterisk in the figure (only the blue one for interrogation).

We thank the reviewer for pointing out this discrepancy. While revising this manuscript, especially for the results section, we adopted a stricter standard for our significance index. Therefore, the association between Focus interoception score and confidence in truths in polygraph condition–previously “marginally” significant ($\beta = 0.15$, 95% CI [−0.02, 0.32], pd = 95.76%) - is now interpreted as non-significant. We have revised the figure to reflect the revised results accordingly (lines XX- XX):

“The higher **Focus** interoception score was significantly associated with an increased confidence in truths in the polygraph (β =0.17, 95% CI [-0.01, 0.34], pd = 97.16%), a consistent pattern, although non-significant, was found for confidence in truth in the interrogation conditions (β = 0.15, 95% CI [−0.02, 0.32], pd = 95.76%).

There are some minor mistakes in language:

* When comparing 'lies' (plural), ensure to also say 'truths' (plural). Especially the methods and results often discuss 'truth' and 'lies'.
* P. 4, line 55: remove "a metacognitive dimension of interoception"; already explained above
* P. 5, line 26: "further reported that individuals"
* P. 7, line 9: the phrasal verb is "pertain to", but perhaps you mean "containing the item Yoni is referring to"?
* P. 8, lines 10-33: This technically is one very long sentence. Perhaps it can be split into: "Given interoception's multidimensional nature, the MAIA-2 (Mehling et al., 2012), a 37-item questionnaire, using a 5-point Likert scale, was also administered. It contains eight distinct facets including […]."
* P. 8, lines 38-41: Perhaps add a note like "taken from their previously completed Autobiographical Memory Questionnaire […]"
* P. 10, lines 12: Abbreviations ECG and EDA are first mentioned, but not written out.
* P. 10, line 58: AMQ has been written out, so can just use the abbreviation
* P. 13, line 4: "The study was not pre-registered (stemming out from […]" (remove 'out' after stemming)
* P. 20, line 39: "al. (2022) further reported that"
* P. 20, line 44: "Mohr et al. (2023) found that"
* P. 22, line 21: "lying skills - rather than of deception self-confidence"
* P. 22, line 39: "concerns regarding its validity have been"
* P. 23, line 14-16: "could emerge with sufficient statistical power"

These have been addressed.

Ensure to follow APA rules regarding numbers in the text: use numerals to express numbers 10 or above and write out numbers as words to express numbers up to nine. Don't start a sentence with numerals. Specifically:

* p. 5, line 42: two conditions
* p. 6, line 18: Thirty university
* p. 6, line 57: four colored
* p. 8, line 12: eight distinct
* p. 11, line 10: three cognitive-behavioural
* p. 11, line 20: three electrodes
* p. 12, line 29: three outcome
* p. 13, line 53: three Yoni-task … two BES
* p. 14, line 3: eight MAIA … three HCT

These have been addressed.

Reviewer #2

I thank the Reviewer for incorporating my suggestions and comments in this revised version of the manuscript which I think is very much improved. I do not have additional comments but I would like to better taken into account a couple of my prior remarks.

The authors cited great work on EF and interoception and lying. They could also think to cite another recent article in which the authors tested different EF and their link with lying: Battista, F., Otgaar, H., Mangiulli, I., & Curci, A. (2021). The role of executive functions in the effects of lying on memory. Acta Psychologica, 215, 103295.

We thank the reviewer for the suggestion. We have included the work by Battista et al. (2021) in our discussion. On lines 364-366:

"Another possibility that should be tested in the future is that of a mediating role of executive functions, given their association with lying (e.g., Battista et al., 2021; Debey et al., 2012) interoception (Molnar-Szakacs & Uddin, 2022)."

2.

Did the authors carried out an a priori analysis to determine their sample size? Please, report this information and if so, please specify on which parameters they based their power analysis. If not, I think the authors should include a sensitivity/posteriori analysis.

This study was not preregistered, and no power analysis was performed to determine the sample size (mostly due to time available and other constraints related to this being part of a student's final year project). To compensate for these major flaws, we have taken a variety of steps, including (in our opinion) an appropriate and conservative statistical treatment (with effect uncertainty quantification and report), a careful discussion emphasizing the limitations, and most importantly, a complete transparency and reproducibility.

On a side and tangential note, we have ourselves carefully examined the data (acting as the first skeptics) and only because we are confident these are interesting patterns did we submit them for publication. Naturally, collecting more data would have been the best, although impossible due to the aforementioned reasons, so treating this study as a preliminary proof-of-concept paper presenting the paradigm and some leads to further investigate and confirm seemed to us like the best option.

We have also investigated the sensitivity/posteriori analysis mentioned by the reviewer, but from our research in seems mostly in the case of discrete outcomes where one can estimate the

sensitivity of their predictive classification models. We would be very interested in any pointers for this type of analysis that the reviewer might have.

Please, add a footnote where you explain this.

We have explained this in a footnote on the title page as follows:

"Note. This study stemmed from a student's Honour's Thesis project. Despite the methodological limitations (i.e., absence of pre-registration and power analysis) in part due to time constraints typical of a student's final year project, there are interesting patterns of results that the authors believe are worthy of discussion and publication. This is against a background of several precautions that the authors have adopted, including a careful examination of the data, conservative statistical treatment, and a detailed outline of the methodology to ensure transparency and reproducibility."

3.

Also, I was surprised to see the authors used physiological measures to understand deception but I understand that the authors mainly used physiological measures to assess interoception and also as an additional measure to self-report ones. However, in their discussion they also claim that physiological measures are good lie detection cues. But, there is a large amount of studies showing that actually physiological measures are not good indicators of deception as they are influence by several individual and situational factors. I think this literature needs to be take into consideration at least while discussing the achieved results.

We agree with the concerns pertaining the accuracy of physiological measures in assessing deception ability. We have highlighted the debate surrounding its implementation as a valid measure in the current body of literature and added the following clarifications (l. 333-336): "By extension, our study adds to the controversial discourse surrounding the use of physiological measures in past deception research, further questioning its validity as an indicator of deception (Oviatt et al., 2018; Rosky, 2013)."

Here, I still think the authors should better frame the debate being more specific on the critiques moved to physiological measurements.

We have revised the discussion to be more specific regarding the limitation of using physiological measurements in deception research (lines 327-336):

"While the impacts of external settings on individuals' responses warrant further investigation, the results highlight how physiological responses can be easily confounded by other factors, independent of whether one is lying or telling the truth. For instance, the presence or absence of

the “interrogator”, or the saliency of the moral nature of the task (e.g. Peleg et al., 2019, argues that the polygraph test alone also acts as a “moral reminder”, framing the possibility that physiological arousal in a polygraph context might be partially a reflection of individuals’ attention directed to their own moral standards). By extension, our study concurs with the controversial discourse surrounding the use of physiological measures in deception research (Rosky et al., 2013; Oviatt et al., 2018).”

4. Finally, a very general comment. Could it be that the concepts of interoception and TOM work together, that is could it be that they influence the ability to lie simultaneously and not in a separate way as it seems was conceived by the authors?

We thank the reviewer for the suggestion, and in essence we very much agree. Indeed, there has been some research linking interoception and ToM, as well as their neurophysiological underpinnings. However, much of this research seems focused on emotion processing, which only constitutes one of the host of cognitive processes required to engage in deceptive behaviour (see Shah, P., Catmur, C., & Bird, G. (2017). From heart to mind: Linking interoception, emotion, and theory of mind. Cortex; a journal devoted to the study of the nervous system and behavior, 93, 220-223.). Furthermore, given the overlaps in the literature surrounding ToM and empathy, it remains unclear whether interoception works with ToM or empathy (specifically affectivce empathy) in the processing of emotions. As such, while we do not reject the possibility of interoception working with ToM in influencing lie ability, considering the current gaps in literature, separating the two constructs and their underlying constructs appeared to be a useful first approach to delineate potential "main effects" of these processes. However, future studies (with a different design and a larger sample) could investigate the interaction (and possible mediation effects) between interoception and ToM by means of, for instance, structural equation modelling.

I thank the authors for their explanation. I suggest them to add this speculation also in their paper, specifically in the Discussion.

We have incorporated this discussion in our limitation section, on lines 327-336:

“Finally, there has been some research in the extant literature linking individual differences in ToM and interoception, as well as their neurophysiological underpinnings (Shah et al., 2017; Gao et al., 2019; Ondobaka et al., 2017). As such, it remains a possibility that the two constructs interact in influencing lying ability. However, much of this research seems focused on emotion processing, which only constitutes one of the hosts of cognitive processes required to engage in deceptive behaviour (e.g., Shah et al., 2017). Furthermore, given the overlaps in the literature surrounding

ToM and empathy, it remains unclear whether interoception works with ToM or empathy (specifically affectivce empathy) in the processing of emotions. Considering the current gaps in literature, the present study investigates the influence of individual differences in ToM and interoception on lying ability separately; this could be a useful first approach to delineate potential "main effects" of these processes. Nevertheless, future studies (with a different design and a larger sample) could investigate the interaction (and possible mediation effects) between interoception and ToM by means of, for instance, structural equation modelling."

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