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# Sense of self in first-time pregnancy

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Kelsey Perrykkad <sup>1,2</sup> , Rebecca O'Neill <sup>2,3</sup> & Sharna D. Jamadar <sup>3</sup>

Pregnancy is a time of profound upheaval of the self, when in addition to undergoing dramatic physical changes to accommodate a developing foetus, significant cognitive and social transformations occur in preparation for birth and parenthood. So far, research into cognitive constructions of the self has been either infant-centric or psychopathology-focused, so our understanding of the healthy, changing self in pregnancy remains relatively poor. This online experiment uses online questionnaires and two cognitive tasks to investigate how constructs relating to the mental self-model, including *body representation*, *self-concept clarity*, *sense of agency*, *general self-efficacy* and *self-attribute learning*, differ between first-time pregnant ( $n = 100$ ) and never-been pregnant ( $n = 102$ ) women. Results indicate that first-time pregnancy is associated with a significantly higher sense of body agency, body visibility, and body estrangement. Poorer accuracy for newly learned associations was also observed in the pregnant group. Whilst a typical self-processing bias was observed in both groups as expected, an intentional binding effect was absent. Notably, post-hoc exploratory analyses provide initial evidence for trimester effects, with a decisively higher self-reported sense of negative agency in the first trimester compared to the never-pregnant group and other trimesters. Further, body agency and self-efficacy were higher in the second-trimester group compared to the never-pregnant group, suggesting a period of relative recovery and consolidation of the new self. Taken together, our results suggest that aspects of self-representation and agency undergo significant shifts over the course of pregnancy and provide multiple exciting avenues for future research.

Throughout childhood and adolescence, we not only discover but actively shape who we are. These processes culminate in a neurally and psychologically represented dynamic model of the self. Here, a 'self-model' refers to the mental representation of oneself, which develops in interaction with one's personal history and experiences, innate characteristics, perception of one's own agency and body representation.

The process of learning about oneself is not confined to early developmental stages<sup>1,2</sup>. The self continues to undergo evolution and redefinition in response to changing circumstances and environments throughout the lifespan. Few periods in life are as marked by rapid and intense evolution and redefinition of the self as pregnancy, when, in addition to undergoing dramatic physical changes to accommodate a developing foetus, significant cognitive and social transformations occur in preparation for birth and (usually) parenthood. Very little research to date has investigated changes to the self in pregnancy (cf. refs. 3–5), and even fewer of these have employed a cognitive approach (cf. refs. 6,7). In this study, we investigate how the self-model differs between first-time pregnant (primigravida) and never-been pregnant (nulligravida) women.

According to the predictive processing framework, at all levels of the cognitive hierarchy, the brain is continuously seeking to reduce discrepancies between what is expected and incoming information it receives from the senses<sup>8–11</sup>. As a result of minimising these discrepancies, a parsimonious explanation of sensory input will result in a model of the self<sup>12</sup>. In combining prior expectations and incoming sensory information iteratively throughout the lifespan to optimise future expectations, this Bayesian approach to self-knowledge blurs boundaries between perception and cognition and unifies traditionally distinct domains of perception and action. The self-model is a reflexive mental representation of who and what, one is. Knowing what kind of being one is forms the basis for their predictions and interactions with the world—from simple interactions with the surrounding environment, informed implicitly by immediate sensory inputs, to situations involving complex reasoning, involving higher order, conceptual predictions that are actively formed on the basis of accumulated experiences<sup>13,14</sup>. Accounting for prediction errors can affect multiple aspects of one's world-model and self-model simultaneously at different levels of this cognitive hierarchy, and how they are accounted for is dependent on

<sup>1</sup>The Centre for Women's and Children's Mental Health, School of Clinical Sciences, Monash University, Clayton, Australia. <sup>2</sup>Cognition and Philosophy Lab, Philosophy Department, School of Philosophical, Historical and International Studies, Monash University, Clayton, Australia. <sup>3</sup>Turner Institute for Brain and Mental Health, Monash University, Clayton, Australia. ✉e-mail: [kelsey.perrykkad@monash.edu](mailto:kelsey.perrykkad@monash.edu)

contextual factors. For instance, a person who scores higher than they predicted on a test multiple times may adjust their expectations for future performance. Such an adjustment may lead to revisions of self-beliefs at varying levels of abstraction; from improved academic capability in a specific subject to enhanced confidence in one's overall intellectual capability, or simply attributing performance to working with a particular teacher. Importantly these changing beliefs will also change how they will act in the future.

When one undergoes a *transformative experience*—a profound, life-altering event—the experience of the self is substantially revised. This has given rise to the use of the term *matrescence* to describe the transition to motherhood as a developmental stage, just as adolescence represents a transition to adulthood<sup>15</sup>. Pregnancy is *epistemically transformative* in that it brings knowledge that could not have been acquired without first-hand experience<sup>16</sup>. Woollard<sup>17</sup> argues that it is extremely difficult for people who have never been pregnant to understand pregnancy, given the combination of multiple, unexpected physical changes and sensations, accommodating another person developing inside one's body, and resulting changes to one's relationship with the self and the body. Pregnancy is also *personally transformative*, changing key self-defining features such as core beliefs, values, preferences, life goals, and identity<sup>16</sup>. Though major transformative experiences such as pregnancy presumably impact the processing of information related to the self, from sensory inputs to broader beliefs and worldviews<sup>18</sup>, how aspects of the self-model may change in the event of such experiences is unclear. There is a nascent literature in predictive processing about related issues, including foetal (self-)development relying on co-embodiment and co-hoemostasis<sup>19–21</sup> but very little if any work focused primarily on *maternal* self-model transformation through this developmental stage.

The transformative experience of pregnancy provides a unique opportunity to study how the maternal brain learns self-related information, as many of the sources of evidence about who we are changing. Pregnant people must learn to attribute sensations from within the body, which have always been attributable to the self, to other sources, including the human foetus. While this may seem trivial, one study showed a significant proportion of women continue to experience 'phantom kicks' postpartum<sup>22</sup>, suggesting individual differences in learning (and relearning) the association between internal sensations and their cause (gastrointestinal vs. foetal movements). In most cases too, pregnant people must learn to embody the new social role of 'mother', which involves adopting a new set of values, goals, and dispositions for action. The combination of these changes across cognitive domains has the potential to alter the self in a dramatic but healthy way. We conceive of this rapid period of learning as a dramatic change in the sources of self-related information as a magnification of the dynamics of daily self-learning, as in more gradual day-to-day changes.

In this study, we comprehensively examine whether the transformative experience of pregnancy changes the self-model. We focus on whether pregnancy is associated with differences in multiple aspects of the self-model. We adopt a broad approach to measuring aspects of the self-model, operationalised as *self-concept clarity*, *sense of agency*, *general self-efficacy*, *body representation*, and *self-biases in learning*. Our over-arching hypothesis is that since pregnancy is a transformative experience, pregnant women will be predisposed to a state of heightened learning about the self. We suggest that this will be reflected in differences between pregnant and non-pregnant people in multiple underlying components of the self-model reflecting both the contents of the self-model and associated cognitive processes contributing to its construction and maintenance.

Self-concept clarity captures how all the features of the self come together to form an integrated whole. It measures the structural integrity of people's beliefs about themselves, including whether they are clearly defined, internally consistent and stable over time<sup>23</sup>. In being structural, self-concept clarity characterises qualities of these beliefs independently of their accuracy, positivity, or potential to influence behaviour. Individuals reporting poorer self-concept clarity have demonstrated lower accuracy in predicting their own behaviour, lower levels of agreement with others in personality

ratings<sup>24</sup>, and higher sensitivity to illusory experiences of the body<sup>25</sup>. Taken together, these findings suggest that low self-concept clarity is associated with a less stable bodily self-representation and sense of agency. However, very few studies consider such a broad range of self-related cognitive processes<sup>26</sup>, so their exact relations are unknown. To our knowledge, self-concept clarity has not been measured in a pregnant cohort. We expect these structural features of the self, clarity, consistency and stability to be in a state of flux in pregnancy, and thus anticipate lower self-concept clarity in pregnancy.

The sense of self affects the actions that one selects based on their values and goals and thus also shapes expectations about what sensations to expect once actions are selected. Confidence that one's actions will be successful implies an expectation that one has a sense of control, or *agency*, over elements of their environment as the initiator of action<sup>27</sup>. Internal signals, such as motor predictions based on the selection of a particular action, can elicit a concurrent *feeling of agency*, subsequently leading to a more explicit *judgement of agency*<sup>28</sup>. Judgements of agency (answering "did you do that?" after the fact) are almost always explicitly assessed through direct questions since they require conscious reflection after the event. Sense of agency may be measured explicitly or implicitly. An explicit measure of *sense of agency* may ask an individual to rate the extent to which they felt they caused a specific event to happen during an action, whilst an implicit measure compares perceptual differences between self- and independently generated action-effects<sup>29</sup>.

The canonical implicit measure of the sense of agency is 'intentional binding'. The 'intentional binding effect' is a perceptual phenomenon where an individual's voluntary actions and their outcomes are perceived as occurring closer together in time than events that are perceived as caused by an external factor or agent<sup>30</sup>. Participants demonstrated stronger intentional binding between the action and outcome when the outcome was a geometrical shape associated with the self, compared to those associated with friends or strangers<sup>31,32</sup>. Given that the geometrical shape and label associations are newly learned in these experiments, these studies suggest that the sense of agency is impacted by self-learning and thus might be affected in transformative experiences such as pregnancy.

The intentional binding task is limited to a specific, contextualised event and does not capture broader cognitive processes that may drive one's sense of agency in everyday life. The sense of agency scale<sup>33</sup> measures the *general sense of agency*—the experience of control over one's thoughts, body, and immediate environment—in a general way, separated from a particular action and outcome pair.

Neither task-based nor self-reported general sense of agency has been measured in a pregnant cohort. With both a changing body and social role, it is reasonable to think that one's action repertoire and the likely outcomes of one's actions are likely to change in this period, thus impacting one's sense of agency during the transition.

*General self-efficacy* is contingent on an individual's sense of agency. *Self-efficacy* refers to one's belief in their own ability to succeed in specific situations or accomplish certain tasks and is a core aspect of human agency<sup>34</sup>. Beliefs about self-efficacy influence one's perceived capabilities, motivation and willingness to persevere through difficulties, and decision-making<sup>35</sup>. Self-efficacy theory originally conceptualised the construct as relating to domain-specific relationships between beliefs about performance and actual performance in a narrow context<sup>36</sup>. For example, research investigating self-efficacy in pregnancy has applied measures such as the *Childbirth Self-Efficacy Inventory*<sup>37</sup>, the *Prenatal Parental Expectations Survey*<sup>38</sup> and the *Self-Efficacy for Parenting Tasks* scale<sup>39</sup>, which emphasise competence in the maternal role, childbirth, infant bonding and tasks relating to infant care, such as breastfeeding.

However, we argue that pregnancy may influence general self-efficacy beyond the domains of maternity and infant care. Success and failure across various contexts combine into a general sense of self-efficacy—constituting baseline beliefs about the efficacy of one's actions in achieving expected and desired outcomes<sup>40</sup>. General self-efficacy has value for explaining behaviour across multiple contexts including novel ones<sup>41</sup>, for predicting positive

health, work, and social outcomes<sup>42–44</sup>, as well as overall life satisfaction<sup>45</sup>. General self-efficacy measures in pregnant populations have typically been applied to measure outcomes associated with specific concerns, such as pregnancy-related back pain, found to be associated with low general self-efficacy<sup>46</sup>; as well as health conditions including diabetes and hyperglycaemia, where high general self-efficacy is associated with better physical condition<sup>47</sup> and health-related quality of life<sup>48</sup>. Self-efficacy in pregnancy has also been linked to postpartum return to work outcomes<sup>49</sup>. However, general self-efficacy has not been compared to other measures of self-related cognition in a pregnant cohort, nor are natural fluctuations across a healthy pregnancy understood.

Body representation refers to internal, multisensory, action-oriented cognitive structures related to one's understanding of their physical form. The plasticity of this representation is evident in its ability to extend beyond the biological body to encompass tools and other objects of interaction<sup>50,51</sup>. Preconscious representations of the body's position in space continuously update as sensory information is acquired from the body and the environment<sup>52</sup>. Body size estimate tasks, where participants match a visual stimulus to the size of their own body, suggest that body representation facilitates our capacity for depictive self-recognition<sup>53</sup>. People with body image disorders such as anorexia nervosa demonstrate distortions in body representation, overestimating their body size irrespective of their weight<sup>54</sup>. Interestingly, pregnancy not only alters the brain's representation of the internal body due to signals associated with foetal growth but also expands the representation of the space around the body in late pregnancy, potentially as a protective mechanism<sup>55</sup>.

Body representation also encompasses more abstract, conceptual representations of the body and its capabilities, such as beliefs about functionality, aesthetic qualities or vulnerability<sup>56,57</sup>. This is typically conceived as *body image*, a term most often used to describe general feelings of satisfaction regarding appearance and body size, especially in regards to weight loss or gain<sup>56,58</sup>, with limited consideration to the complexity of women's bodily experiences. However, qualitative studies have revealed common themes regarding broader somatic experiences of the body during pregnancy, where dramatic physical changes occur in tandem with an emerging self-identity as a parent<sup>59</sup>, including beliefs related to functionality and strength of the body, femininity, sharing the body with another organism, a disrupted sense of control, and, the highly visible and public nature of the growing body<sup>57</sup>. The *Body Experiences During Pregnancy Scale*<sup>57</sup> includes three subscales encompassing these themes: body agency, involving appreciation of the body and its functionality; body estrangement, referring to a sense of disrupted connectedness to the body as it accommodates a growing foetus; and body visibility, involving attention and social commentary towards the pregnant body. Mooney et al.<sup>60</sup> found a significant association between body agency and wellbeing during pregnancy, that high levels of body estrangement were associated with lower levels of mindful self-care behaviours, and that body estrangement was related to high levels of prenatal distress when mindful self-care behaviours were low. However, as no previous study has compared these experiences with a non-pregnant cohort, it is unclear how many of these experiences are pregnancy-specific and how many of them are shared by other people, including women with eating disorders or mental conditions affecting the self, such as schizophrenia.

To understand transformations of the self-model in pregnancy, we must also consider the learning processes involved in constructing and maintaining it. In general, information related to the self has priority over information that does not, both consciously and subconsciously<sup>61</sup>. Self-related information automatically attracts attention<sup>62,63</sup>, for instance, one will respond to their own face faster than those of other people<sup>64,65</sup>. This *self-reference effect* enhances the binding of different forms of information relating to the self, with individuals demonstrating better encoding, recall and processing compared to non-self-related data<sup>66</sup>. Children as young as four demonstrate clear memory advantages for items encoded with reference to self, such as recalling more items presented with photographs of their own face compared to a stranger<sup>67,68</sup>. In adulthood, the self-reference effect

may be enhanced by additional processes related to executive function, such as increased arousal and attention<sup>63,69</sup>, as well as conscious self-reflection<sup>66,70</sup>.

Self-prioritisation effects are apparent even with inconsequential, equally familiar stimuli. In the shape-label matching task<sup>61</sup>, shapes (e.g., square, triangle, circle) are associated with labels of varying personal significance (e.g., self, friend, stranger). On this task, participants respond faster and more accurately to trials where self-shapes are presented<sup>61,71–73</sup>, consistent with the argument that self-related stimuli are processed faster or take priority, by comparison to non-self-related stimuli.

Only recently, one published study and one preprint have investigated perceptual self-bias effects within the few years postpartum<sup>67</sup>. Hoegholt et al.<sup>6</sup> found that the classic self-bias in a shape-label matching task switched to an infant-bias for parents one year postpartum, which differed significantly from those same couples when they were trying to conceive and from non-parents. Consistent with this, Jiang and Sui<sup>7</sup> found that attentional prioritisation and recognition of own name was diminished in mothers who were one to two years postpartum. Despite this limited evidence that shows changes to cognitive processes related to attention, learning, and recognition of the self in the postpartum period, to date, no study has investigated whether such differences begin in pregnancy or how they fluctuate throughout matrescence. We hypothesise that pregnancy is a period of disruption to these processes, with some individual variability. This may lead to diminished perceptual self-prioritisation as one prepares to attend to a vulnerable baby or improved perceptual self-prioritisation as the brain pays special attention to information that is rapidly changing (increased learning rate).

In this preregistered study (<https://osf.io/vua52>), we combine evidence from questionnaires and cognitive tasks with the aim of better understanding the ways in which the experience of pregnancy is related to changes in the self-model, as measured by self-concept clarity, sense of agency, general self-efficacy, body representation, and self-biases in learning. We hypothesised that pregnancy is a period of disrupted self-representation and this will be reflected as differences between pregnant and non-pregnant women across multiple measures. Taking a Bayesian approach, if the evidence in favour of the null is found, this will be taken as evidence that that aspect of the self does not change with pregnancy (or at least not in a consistent way across pregnancies).

## Methods

This study was approved by the Monash University Human Research Ethics Committee (Project Number 32109) and was conducted in accordance with the relevant guidelines and regulations. All participants gave informed consent upon commencing the protocol. The data presented here were collected, processed and analysed according to preregistration registered in the OSF platform (<https://osf.io/vua52>). All analyses below are clearly indicated as planned or exploratory in line with this preregistration. The dataset used for statistical analysis and the preprocessing script is freely available as part of the project “Self in Pregnancy—Shape-label matching, Intentional Binding, and Self-Report” on the OSF platform (<https://osf.io/9mhbg/>).

As reported in our preregistration, we estimated our required sample size prior to data collection using G\*Power 3.1.9.7, and it was determined that a sample of 75 in each group would give adequate power of 0.86, and accounting for expected attrition, we would aim to initially collect 100 participants in each group (power = 0.94) and, if practicable continue to collect to this maximum if there is no decisive evidence for the hypothesised group differences or the main replications do not hold (as was the case).

## Data collection and exclusion

Eleven participants were recruited through word of mouth (6 primigravida, 5 nulligravida); and were entered into a draw to win a \$50 gift card. A total of 262 participants recruited from the Prolific online participant recruitment platform successfully completed the study. Data were collected between 3 June and 30 November 2022. Details of recruitment on the Prolific platform are reported in the Supplement.

Eligibility criteria included being assigned female at birth, being fluent in English, having normal or corrected-to-normal vision, having no previous pregnancy, having no biological or non-biological children, having no history of neurological damage or disorder, being over 18 years of age and not being menopausal or post-menopausal.

The initial planned data collection of 100 participants per group was completed in August 2022, and quality control checks left 84 nulligravida participants and 64 primigravida participants. Further, Bayesian analysis indicated that there was not enough data for some of the key comparisons to make a definitive judgement based on the evidence, and other classic findings did not give the usual result, so in line with our preregistration, collection to a total of 100 quality participants in each group was attempted on Prolific. Participant and trial elimination criteria were not changed following the initial data collection period. Data collection was stopped when the final dataset consisted of exactly 100 primigravida participants with quality data (the aim of 100 in the nulligravida group exceeded this intended maximum by two who mistakenly participated through the primigravida advertisement during the final days of data collection). The final dataset thus contains six participants recruited through word of mouth (3 in each group), 97 primigravida and 99 nulligravida participants recruited through the Prolific platform.

### Materials and procedure

Participants first completed a demographic survey and the questionnaire measures in a random order which measured Self-Concept Clarity<sup>23</sup>, General Sense of Agency<sup>33</sup>, General Self-Efficacy<sup>40</sup>, and Body Experiences During Pregnancy<sup>57</sup>. Participants then completed two cognitive tasks matching those in ref. 32: the shape-label matching task, measuring self-bias towards arbitrary and newly learned self-associations<sup>71</sup>, and an intentional binding task<sup>30</sup>, which is an implicit sense of agency measure based on perceived temporal compression. These cognitive tasks were custom programmed using Psychopy Builder and custom PsychoJS code and presented with PsychoJS version 2021.2.3 on the Pavlovia online platform<sup>74</sup>. In both tasks, the Pavlovian task window was forced into fullscreen on every trial to discourage (or effectively prohibit) multitasking. Each of these measures is described fully in the Supplement. Summary scores submitted to analysis for each scale are briefly described below.

**Self-concept clarity.** Summed<sup>23</sup> score, such that greater values represent increased self-concept clarity.

**Sense of agency.** Two summed<sup>33</sup> scores, positive sense of agency and negative sense of agency. Captures differences in experiences of being in and out of control of one's actions and their consequences. Higher positive sense of agency scores represents more often having experiences of being in control in daily life. Higher negative sense of agency scores indicate more often having experiences of being out of control.

**General self-efficacy.** Summed score<sup>40</sup>, where higher scores indicate a more confident belief that one is capable of achieving one's goals

**Body experiences during pregnancy.** We adapted<sup>57</sup> this scale to accommodate its use in pregnant and nulligravida groups. Three mean scores are calculated from relevant items. Higher scores on the body agency subscale indicate greater feelings of attractiveness, femininity, pride, competence and self-confidence. Higher scores on the body estrangement subscale indicate feelings of less control, less ownership, and poorly defined boundaries. Higher scores on the body visibility subscale indicate that the body is stared at, touched, or evaluated more.

Following the questionnaire, participants completed a pair of cognitive tasks<sup>32</sup> which gave us behavioural measures of perceptual bias and agency in the context of newly learned self-information. Further details of the tasks are included in the Supplement. These measures were:

**Shape-label matching task.** A measure of implicit biases towards newly self-associated stimuli<sup>71</sup>. Measures of reaction time (milliseconds) and  $d'$  which is a signal detection theory measure with higher values indicating greater sensitivity to detecting the signal (associated pairs).

**Intentional binding task.** A task-based measure of sense of agency and judgement of agency. An interval reproduction method was used, which represents the duration of time perceived by the participants between their action (or a visual stimulus in the control condition) and the presented shape. A measure of intentional binding, which subtracts the reproduction interval in the action condition from the control visual condition, was also created for each participant for each identity so that greater values indicate more binding (agency). A judgement of agency probe was present in half the trials, with higher scores indicating a higher consciously perceived sense of control over the previous trial. In the other half of the trials, a memory probe asked participants which identity matched the shape they had just seen.

### Statistical analysis

Data aggregation and cleaning were performed using R version 4.2.2. In line with our preregistration, statistical analysis was conducted using Bayesian statistics as implemented in JASP 0.16.4. Instead of resulting in a p-value, which indicates the likelihood of observing data at least as extreme if the null-hypothesis were true, as in null hypothesis significance testing approaches, Bayesian analysis gives a Bayes factor (BF), which represents a ratio of how likely the data are to occur under different hypotheses in the order of the subscript (where the alternative hypothesis is denoted by 1 vs. the null hypothesis by 0) (see ref. 75 for a non-technical introduction to this approach, and ref. 76 for more detailed comparisons with the more traditional frequentist statistics). For all Bayesian analyses,  $BF_{10} > 1$  is interpreted as weak confirmatory evidence against the null,  $BF_{10} > 3$  as substantial evidence (sometimes considered the boundary for 'significance'),  $BF_{10} > 10$  as strong evidence,  $BF_{10} > 30$  as very strong and  $BF_{10} > 100$  as decisive evidence following Jeffreys<sup>77</sup>. An advantage of Bayesian statistics is that evidence for the null hypothesis can also be reported, so 'null-results' can be made informative as evidence against the alternative is computed ( $BF_{01}$ ). For all analyses here, the default prior in JASP was used. For repeated measures ANOVAs, this was a uniform distribution. For independent samples  $t$ -tests it was a Cauchy distribution with a scale of 0.707. For all survey measures in all analyses,  $z$ -scores relative to the whole sample were used.

A correlation matrix for all variables was inspected and is reported in supplementary materials.

**Survey measures.** Bayesian independent samples  $t$ -tests were conducted to assess whether Self-Concept Clarity, Sense of Positive Agency, Sense of Negative Agency, General Self-Efficacy, Body Agency, Body Estrangement or Body Visibility differed between the primigravida and nulligravida groups. *Exploratory Analyses:* Although unplanned, there was a relatively even distribution of the primigravida group across trimesters. As such, an additional one-way ANOVA was also conducted for each survey measure to cross-sectionally explore changes to these experiences throughout pregnancy. For this and similar analyses, nulligravida women were categorised as 0, and primigravida women were given a number 1–3, indicating their self-reported current pregnancy trimester.

**Shape-label matching task.** A Bayesian  $3 \times 2$  repeated measures ANOVA was used to assess the impact of shape Identity and Group on  $d'$  in the shape-label matching task. A similarly structured  $2 \times 3 \times 2$  repeated measures ANOVA was used to detect differences in reaction time based on shape-label Congruency, shape Identity and Group. Self-bias measures for  $d'$  and reaction time were compared between groups using a Bayesian independent samples  $t$ -test. *Exploratory Analyses:* The ANOVA analyses were repeated with a trimester categorisation as well as the



binary pregnancy group variable, and one-way ANOVAs were run for the self-bias measures to compare trimester groups.

**Intentional binding task.** A Bayesian  $3 \times 2 \times 3 \times 2$  repeated measures ANOVA was used to test the effect of shape Identity, Condition, Delay and Group on the reproduction interval. Self-bias measures were compared between groups using a Bayesian independent samples *t*-test. The post-trial memory probes were compared using a  $3 \times 2$  Bayesian repeated measures ANOVA with the factors shape Identity and Group. The judgement of the agency probe was compared using a  $3 \times 2$  Bayesian repeated measures ANOVA with the factors Condition and Group. *Exploratory Analyses:* The ANOVA analysis was repeated with a trimester categorisation as well as the binary pregnancy group variable, and one-way ANOVAs were run for the self-bias measure to compare trimester groups. Exploratory analyses were performed to limit the analysis to just the action condition, and removing the condition as a factor to most closely replicate the design of Makwana and Srinivasan<sup>32</sup> did not change the pattern of results, so they are not reported below. There was a group of participants ( $n \approx 10$  per group) that reported no judgement of agency (average Likert rating  $< 2$ ) in either the action or visual conditions. Exploratory analyses showed that removing these participants from all of the analyses above does not change any of the results except the Sense of Negative Agency findings, which is noted as part of the results below.

## Results

Descriptive statistics for all raw survey scores, self-bias measures, and signal detection theory measures for the shape-label matching task can be found in the Supplementary Materials.

### Participant demographics

Full details of participant demographics are reported in Table 1 (continuous variables are binned for distribution representation). All participants were assigned-female-at-birth, and all reported gender identities that conformed with that assignment except one nulligravida non-binary/gender non-conforming individual. There was no significant difference in age between groups ( $BF_{01} = 5.23$ ) or hours of unpaid employment per week ( $BF_{01} = 16.05$ ). The pregnant group had, on average one more year of formal education (16.6: 17.57 years,  $BF_{10} = 6.04$ ), were less likely to report a history of mental illness (difference of 13%,  $BF_{10} = 3.57$ ), were more likely to have some hours of paid employment per week ( $BF_{10} = 76.58$ ) and reported fewer hours of study per week ( $BF_{10} = 218.05$ ) than the nulligravida group. No decisive evidence for or against a difference between groups was found for estimations of relative income ( $BF_{10} = 1.08$ ).

### Self-Concept Clarity

There was substantial evidence for no difference between nulligravida and primigravida groups on Self-Concept Clarity ( $BF_{01} = 6.53$ ; Fig. 1a) and strong evidence against an effect of trimester ( $BF_{01} = 11.56$ ).

### Sense of Agency

Results show evidence for no difference between groups ( $BF_{01} = 6.47$ , Fig. 1f) or trimesters ( $BF_{01} = 10.88$ ) for Sense of Positive Agency.

Weak evidence for a difference in Sense of Negative Agency between groups ( $BF_{10} = 1.93$ , Fig. 1g) suggests that the pregnant group had more feelings of negative agency than the nulligravida group. Interestingly this seems dependent on the inclusion of participants who report no Judgement of Agency in either the Visual or Agentive condition of the Intentional Binding task (without them, evidence swings equally in the other direction  $BF_{01} = 2.07$ ), suggesting an alignment between Judgement of Agency and Sense of Negative Agency questionnaire scores. Exploratory analysis splitting the pregnancy group into trimesters shows decisive evidence for an effect of the trimester ( $BF_{10} = 1056.02$ , Fig. 2a) such that a Sense of Negative Agency is decisively higher in the first-trimester group than the nulligravida group ( $BF_{10} = 1343.78$ ) and the third-trimester group ( $BF_{10} = 294.82$ ), and substantially higher than the second trimester ( $BF_{10} = 4.15$ ).

### General Self-Efficacy

Evidence between groups ( $BF_{01} = 1.09$ ; Fig. 1b) and across trimesters ( $BF_{10} = 1.52$ ; driven by  $BF_{10} = 6.76$  evidence that self-efficacy is increased in the second trimester compared to nulligravida) is of a magnitude barely worth mentioning, suggesting that more data is needed to determine whether General Self-efficacy is different in pregnancy.

### Body Experiences in Pregnancy

All three subscales of the Body Experiences during Pregnancy Scale showed significantly higher scores in the primigravida group than the nulligravida group (Body Agency:  $BF_{10} = 6.80$ ; Body Estrangement:  $BF_{10} = 5056.83$ ; Body Visibility:  $BF_{10} = 57153.56$ ; Fig. 1c–e), which was not established in Talmon and Ginzburg's original paper<sup>57</sup>, but reflects their design for the survey's use in capturing particular experiences of the body during pregnancy. Splitting the pregnancy group into trimesters suggests that for Body Agency, only the second-trimester group shows substantial evidence for an increase as compared to the nulligravida group ( $BF_{10} = 6.76$ , Fig. 2b). This indicates that participants feel more feelings of attractiveness, femininity, pride, competence and self-confidence in the second trimester than individuals who are not pregnant. Both Body Estrangement and Body Visibility were elevated across all three trimesters compared to the nulligravida group (Body Estrangement: 1st  $BF_{10} = 3272.502$ , 2nd  $BF_{10} = 41.663$ , 3rd  $BF_{10} = 3.551$ ; Body Visibility: 1st  $BF_{10} = 73.66$ , 2nd  $BF_{10} = 206.84$ , 3rd  $BF_{10} = 9913.77$ ) which is perhaps surprising as the physical size of the body notably increases with trimester, but there is weak to substantial evidence against perception of body visibility and body estrangement changing significantly.

### Shape-label Matching

The winning model ( $BF_{10 \text{ Null}} = 5.05 \times 10^{33}$ ) in the Bayesian ANOVA analysis for  $d'$  had both Identity ( $BF_{\text{inclusion}} = 1.72 \times 10^{14}$ ) and Group ( $BF_{\text{inclusion}} = 4.38$ ) as main effects (Fig. 3). Post hoc analyses showed that all identities were decisively different, with the highest sensitivity to self-shape matching, then relative, then stranger. This is consistent with previous literature. The post hoc analysis for the pregnancy effect showed that the pregnant group had lower  $d'$ , indicating poorer accuracy, than the nulligravida group ( $B_{10U} = 237.22$ ). No interactions were significant, indicating that this difference held across all identities. Exploratory analyses which split the participants of the primigravida group into three trimesters shows that this effect depends on trimester (Fig. 4), with only the first ( $BF_{10U} = 69.43$ ) and third ( $BF_{10U} = 24.83$ ) groups showing impaired performance compared to the nulligravida group. There was weak evidence for no difference between the second-trimester group and nulligravida ( $BF_{01U} = 2.92$ ) or the second-trimester group and the other two trimester groups (first:  $BF_{01U} = 1.08$ ; third:  $BF_{01U} = 1.38$ ).

The winning model ( $BF_{10 \text{ Null}} = 3.26 \times 10^{168}$ ) in the Bayesian ANOVA for reaction time (RT) had main effects of Identity, Congruency—and an interaction between Identity and Congruency (for all three,  $BF_{\text{inclusion}} = \text{inf}$ ). Post hoc analyses showed that this study replicates the standard effects for RT in this task, with fastest responses for self, then relative, then stranger shapes (all decisively different  $BF_{10U} > 9.371$ ), and faster responses for congruent compared to incongruent pairs ( $BF_{10U} = 4.87 \times 10^{92}$ ). Post hoc pairwise tests for the interaction showed evidence for differences between all identities only in the congruent condition (Stranger vs. Relative:  $BF_{10} = 3.35$ , Relative vs. Self:  $BF_{10} = 2.28 \times 10^{29}$ , Stranger vs. Self:  $BF_{10} = 2.72 \times 10^{38}$ ). For incongruent trials, there was weak evidence against a difference between relative and self-shapes ( $BF_{01} = 2.04$ ), substantial evidence against a difference between stranger and relative shapes ( $BF_{01} = 3.33$ ), and strong evidence against a difference between stranger and self-shapes ( $BF_{01} = 11.67$ ). The largest observed difference was in the congruent condition for self-identity, consistent with previous literature. There was substantial evidence against an effect of pregnancy status ( $BF_{\text{inclusion}} = 0.12$ ) or a trimester effect ( $BF_{\text{inclusion}} = 0.049$ ) in RT.

Independent samples *t*-tests show substantial evidence against a difference in either  $d'$  ( $BF_{10} = 0.16$ ) or RT self-bias ( $BF_{10} = 0.22$ )

**Table 1 | Demographic Information**

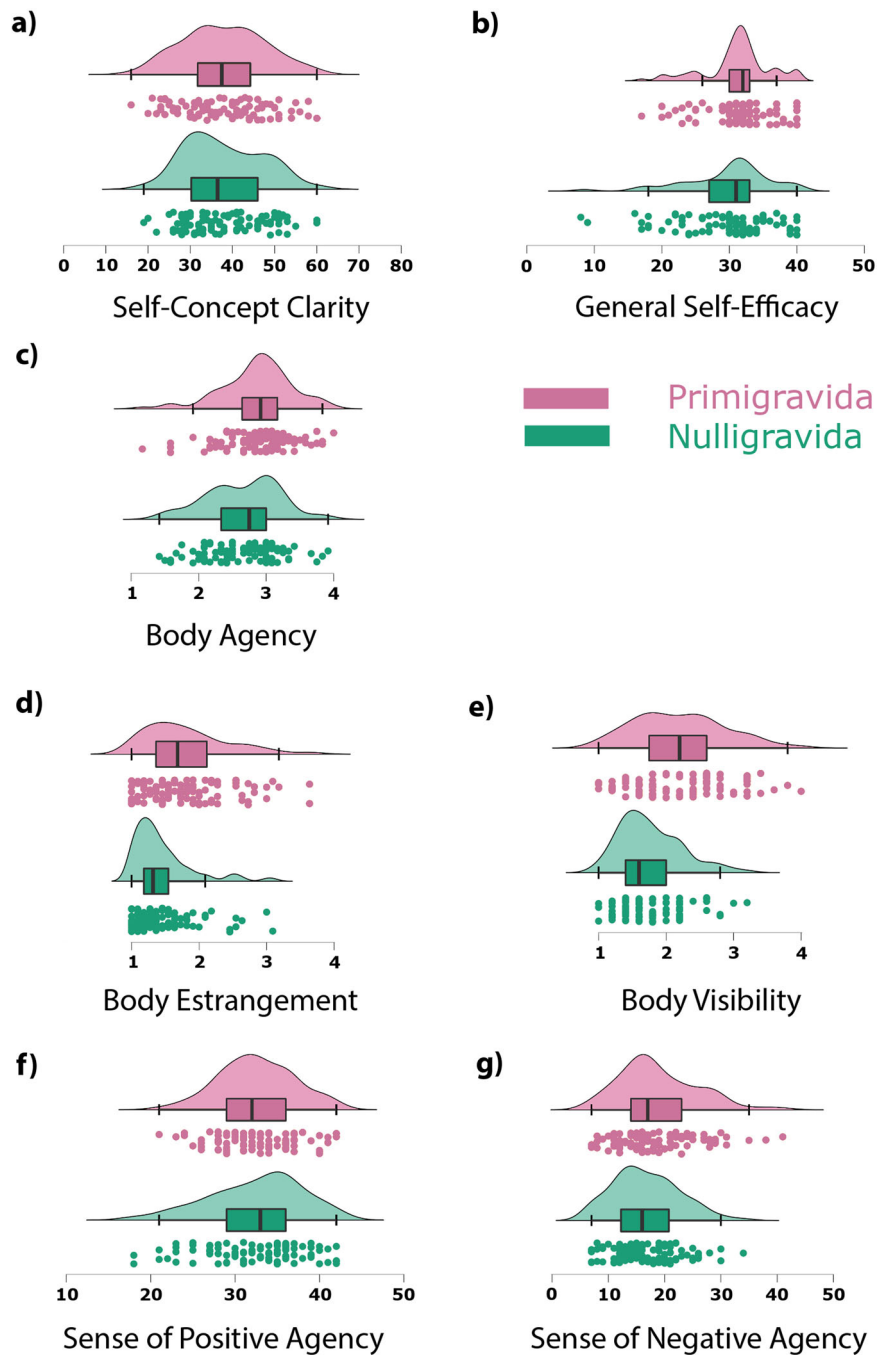
Demographic	Category	Nulligravida (count)	Primigravida (count)	
Age	18–24	33	20	
	25–31	43	51	
	32–38	18	27	
	39–45	6	2	
	46–50	2	0	
Country of birth	United Kingdom	20	29	
	South Africa	8	22	
	United States	19	8	
	Mexico	14	6	
	Australia	10	6	
	Poland	4	3	
	Canada	3	3	
	Italy	5	1	
	Portugal	4	1	
	Chile	2	1	
	Nigeria	0	3	
	(2 each total) China, Estonia, France, Germany, Greece, Hong Kong, Latvia	7	7	
(1 each total) Bulgaria, Colombia, Croatia, Czech Republic, India, Indonesia, Ireland, Malaysia, Philippines, Romania, Russia, Slovenia, Spain, Turkey, Ukraine, Zimbabwe	6	10		
Years of formal education	<=13 (~high school)	12	4	
	14–18 (~undergrad)	69	61	
	19–21 (~masters)	19	28	
	22+ (~doctorate)	2	5	
	NA	0	2	
Estimated relative income	Much greater than average	1	1	
	Greater than average	15	25	
	Average	48	55	
	Less than average	29	15	
	Much less than average	9	4	
Hours in paid employment per week	0	29	8	
	1–15	9	5	
	16–30	12	17	
	30–50	51	64	
	50+	1	3	
	I am on paid parental leave	0	3	
Hours in unpaid employment per week (e.g., cleaning, cooking, caregiving)	0	41	30	
	1–15	47	55	
	16–30	10	11	
	30–50	1	2	
	50+	3	2	
Hours spent studying per week	0	57	66	
	1–15	19	20	
	16–30	9	14	
	30–50	9	0	
	50+	8	0	
History of mental illness	Yes	24	11	
	Diagnosed with	Depressive disorders	10	3
		Anxiety disorders	15	5
		Schizophrenia spectrum or psychosis	0	1

**Table 1 (continued) | Demographic Information**

Demographic	Category	Nulligravida (count)	Primigravida (count)
	Obsessive-compulsive	2	1
	Eating disorders	1	1
	Personality disorders	1	0
	Trauma and stressor disorders	2	2
	No	78	89

**Fig. 1 | Raincloud plots for survey data differences between primigravida and nulligravida groups.**

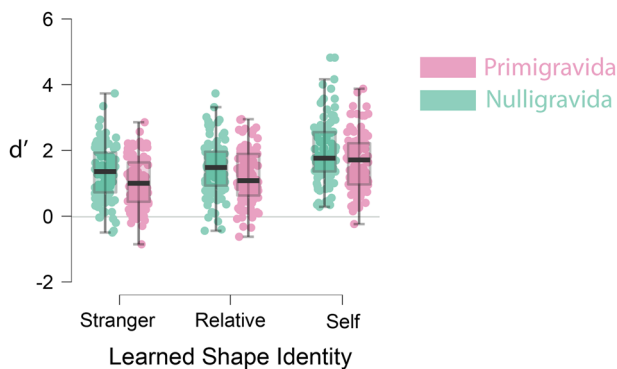
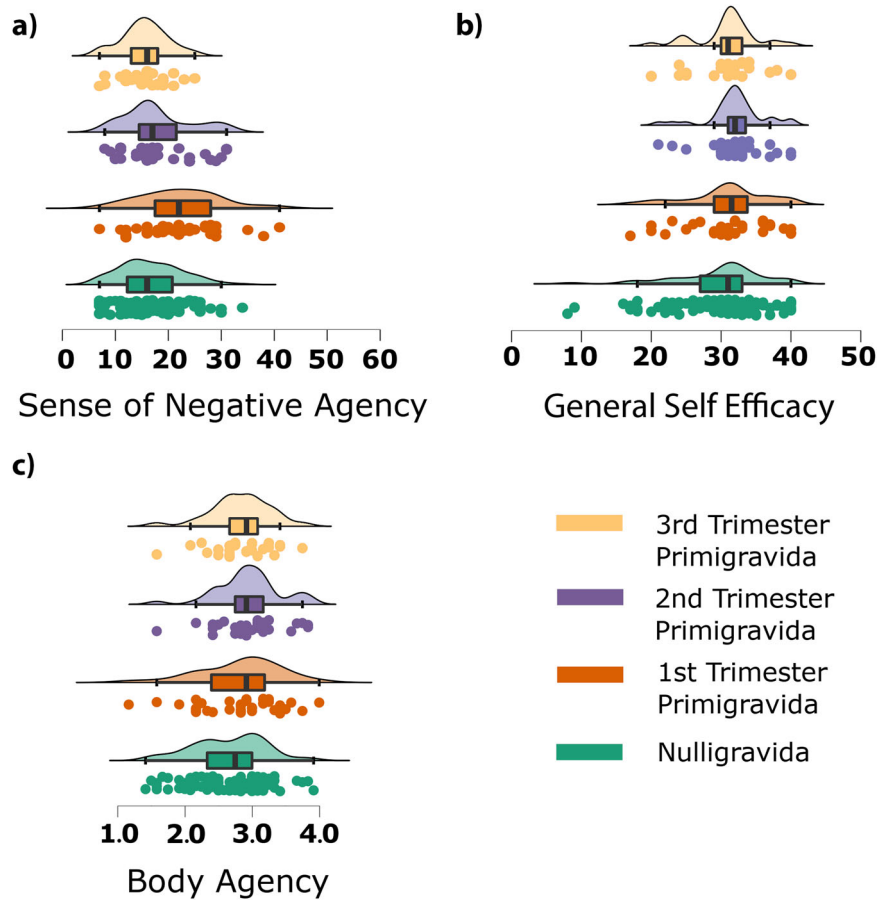
Raw scores depicted here as scattered dots to show original spread, but z-scores were used for all analyses. Boxplots depict median value (centre bar), 25% and 75% interquartile range per standard R boxplot code. Results from each survey are depicted in a separate raincloud plot, such that **a** depicts Self-Concept Clarity scores, **b** General Self Efficacy scores, **c–e** depict subscale scores from the Body Experiences During Pregnancy scale with mean scores depicted for **c** Body Agency, **d** Body Estrangement, and **e** Body Visibility, and **f, g** depict Sense of Positive and Negative Agency from the Sense of Agency Scale, respectively.



between primigravida and nulligravida groups, and exploratory ANOVAs showed evidence for no differences by trimester ( $d'$  self-bias:  $BF_{10} = 0.09$ ; RT self-bias:  $BF_{10} = 0.04$ ). This suggests that primigravida and nulligravida groups were equally biased towards newly acquired arbitrarily assigned self-related information. One sample  $t$ -

tests showed decisive evidence for a difference from 0 for both the  $d'$  ( $BF_{10} = 1.34 \times 10^{26}$ ) and RT ( $BF_{10} = 2.72 \times 10^{38}$ ) self-bias measures. These results indicate that both groups were faster in responding and more sensitive to stimuli associated with the self than to strangers.

**Fig. 2 | Raincloud plot showing evidence for differences by trimester.** Nulligravida n=102, first trimester n=36, second trimester n=35, third trimester n=29. Boxplots depict median value (centre bar), 25 and 75% interquartile range per standard R boxplot code. **a** depicts raw data from the Sense of Negative Agency subscale of the Sense of Agency Scale, **b** raw General Self Efficacy scores, and **c** mean Body Agency subscale scores from the Body Experiences During Pregnancy Scale.



**Fig. 3 | Sensitivity to matching pairs of labels and shapes, compared by group and shape-identity.** Nulligravida group boxplot and individual markers on the left, and primigravida group boxplot and markers to the right for each identity. Boxplots depict median value (centre bar), 25% and 75% interquartile range, and outliers lying beyond the ends of the bars, which represent the most extreme datapoint, which is no more than the range times the box width per standard R boxplot code.

**Intentional binding**

The winning model ( $BF_{10 \text{ Null}} = 3.42 \times 10^8$ ) for the Bayesian ANOVA assessing factors that impacted reproduction intervals showed only a significant effect of Delay ( $BF_{inclusion} = 4.45 \times 10^7$ ). This indicates that participants understood the task and were perceiving differences in duration between event 1 and event 2. However, surprisingly, there was evidence against including the other variables, including condition ( $BF_{inclusion} = 0.034$ ), Identity ( $BF_{inclusion} = 5.04 \times 10^{-4}$ ), and Group ( $BF_{inclusion} = 0.024$ ). This means that there was evidence *against* a classic

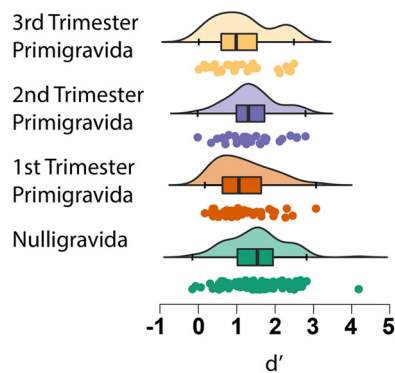
intentional binding effect, evidence against an effect of shape Identity (event 2) on the perceived time between events (contrary to ref. 32), and no difference between groups.

There was evidence for no difference between groups for the intentional binding ( $BF_{01} = 6.51$ ) and action condition reproduction interval ( $BF_{01} = 5.70$ ) self-bias measures or difference from 0 ( $BF_{01} = 7.99$ ;  $BF_{01} = 7.14$ ). This indicates no evidence for bias towards the self-shape on the intentional binding task (cf. ref. 32) and no pregnancy-related differences.

The analysis of the memory probe following the intentional binding task showed a slight preference for an effect of ID ( $BF_{10 \text{ Null}} = 1.12$ ), but this model was not significantly different from the null model, and across all models, it was slightly less probable to include ID than to exclude it ( $BF_{inclusion} = 0.75$ ). Exploratory post hoc analyses nonetheless showed a significant increase in the accuracy in memory for relative compared to self-shapes ( $BF_{10} = 3.51$ ), but there was borderline evidence for the null hypothesis against memory for relative being greater than that for stranger shape ( $BF_{10} = 0.32$ ). This marginal effect appears to be a potential boost to memory for the relative shape rather than a self-specific memory deficit. Exploratory self-bias measures for the memory probe were also created. Evidence for memory differences showed evidence barely worth mentioning of being lower for self than others ( $BF_{10} = 1.76$ ) but was not different between groups ( $BF_{10} = 3.36$ ).

The winning model ( $BF_{10 \text{ Null}} = 3.22 \times 10^{43}$ ) for the judgement of agency analysis shows a main effect of condition ( $BF_{inclusion} = \text{inf}$ ). Post hoc analyses show that participants reported that they felt more in control over the second stimulus in the action condition compared to the visual condition ( $BF_{10U} = 4.61 \times 10^{34}$ ), as expected. This confirms that the lack of intentional binding effect (an implicit measure of agency) is not because of a perceived lack of agentive difference between conditions. No differences in this judgement of agency effect were detected by trimester ( $BF_{10} = 0.04$ ).





**Fig. 4 | Raincloud plot showing sensitivity to matching pairs of labels and shapes, compared by trimester.** Nulligravida  $n = 102$ , 1st trimester  $n = 36$ , 2nd trimester  $n = 35$ , 3rd trimester  $n = 29$ . Boxplots depict median value (centre bar), 25% and 75% interquartile range and outliers lying beyond the ends of the bars, which represent the most extreme datapoint, which is no more than the range times the box width per standard R boxplot code.

## Discussion

This study sought to investigate changes in aspects of the psychological self-model during pregnancy by comparing the differences between pregnant women (primigravida) and non-pregnant women (nulligravida). We focused on five sub-constructs of the self-model: self-concept clarity, sense of agency, general self-efficacy, body experiences during pregnancy, and cognitive bias towards self-related stimuli.

Beginning with the self-report measures, there was evidence for no difference between groups in self-concept clarity. This indicates that the perceived structure of the self, captured by the clarity of its definition, consistency between elements, and stability over time, does not change in pregnancy, contrary to our hypothesis. Given that this is self-reported, it may suggest that the unstable elements that were found to change in our study either did so subconsciously, imperceptibly slowly, or were not salient to participants when answering these more general questions. Results did show weak evidence for a higher sense of negative agency in the primigravida group, indicating that pregnant women endorsed explicitly feeling a lack of agency more often in their lives than the nulligravida group. There was, however, evidence for no difference between groups in the sense of positive agency. The discrepancy between self-reported sense of positive agency and sense of negative agency is consistent with scoring them separately<sup>33</sup>, which means that an individual can score high on both subscales if they have more experiences relating to their agency than individuals who score low on both. Despite being moderately anticorrelated among participants (see Supplementary Materials), our results indicate that pregnant women feel in control of their lives just as often or as much as nulligravida women (sense of positive agency) but more often feel out of control (sense of negative agency). There was not enough evidence to determine whether or not self-efficacy differed between groups, so further research is needed to determine how perceptions of context-general competence change in pregnancy, if at all. The Body Experiences during Pregnancy Scale provided evidence that body estrangement, body visibility, and body agency are significantly higher in primigravida women than in nulligravida women. Together, these results suggest that during their first pregnancy, women report feeling less control and ownership over their bodies, that their bodies are stared at, touched and evaluated more, but also that they feel more attractiveness, femininity, pride, competence and self-confidence. In contrast to earlier studies<sup>57,60,78</sup>, here, we adapted the Body Experiences scale to include a non-pregnant cohort, so this result confirms that these experiences related to the body are significantly different in pregnancy compared to women in the general population.

For the task-based measures, consistent with previous literature, both groups demonstrated a cognitive bias towards self-related stimuli, with participants having a higher sensitivity to self-associated shapes than those

matched to relatives or strangers. While there was evidence for no difference in the strength of this bias between groups, our accuracy measure ( $d'$ ) was significantly poorer for primigravida women than nulligravida women across all identities. It is notable that there was evidence for no difference in reaction times across the two groups, suggesting that it is not a difference in speed-accuracy trade-off between groups<sup>79</sup>, but rather a decrement in recognising the presence of newly learned associations in the primigravida compared to nulligravida group.

In summary, there were significant differences between primigravida and nulligravida participants suggesting a change in aspects of the self, such as in experiences of the body and learning processes, including for novel self-associated stimuli, but no differences in others, such as self-concept clarity. While our Bayesian analysis indicated substantial or greater evidence to determine an outcome for most of the constructs measured, self-efficacy was one area with inconclusive findings, which should be followed up in future research. Taken together, these results suggest that there are substantial changes to some aspects of the self-model in pregnancy. Our findings also support the idea that changes to wide-reaching cognitive mechanisms, such as learning, also affect the self-domain, as seen in the accuracy results from our learning task, where learning was poorer across the board, and the differences between groups were not significantly better or worse for the self condition.

## Trimester results

Most notably, data from our exploratory analysis of trimester effects revealed evidence for an effect of trimester on a number of measures, including cognitive bias toward self-stimuli, body representation, sense of agency, and self-efficacy, suggesting that changes to the self-model are related to the *stage* of pregnancy. These results provide preliminary evidence for the dynamics of self-changes in pregnancy and should be confirmed with a longitudinal design. For instance, the increased sense of negative agency appears to be more pronounced during the first trimester, indicating that women in early pregnancy particularly feel a lack of control over actions and their consequences. There are many factors that may contribute to such an effect in early pregnancy, perhaps the most salient being disruption resulting from the rapid and substantial physical and hormonal changes that occur soon after conception, which include symptoms of morning sickness, fatigue, and appetite changes in over 75% of women which they have no control over<sup>80,81</sup>. It is also the time when the person must accept that a shift to the role of 'mother' is imminent, but at an early stage where the process happens to them and they may not feel they have an active role to play yet. Ross<sup>82</sup> describes the experience of early pregnancy as a time characterised by a sense of heightened risk of miscarriage, as well as secrecy, as pregnancy is often not announced until the end of the first trimester, leading to a lack of wider social support. This occurs in the context of frequent contact with health professionals, medical and technological interventions such as ultrasounds and foetal heart rate monitoring, which may be perceived as heightened surveillance<sup>83</sup>. Again, these elements may contribute to the sense that one is a passive recipient of news as to the progress of the pregnancy without much intentional control over its outcome.

By contrast, the second trimester may be a relatively consolidated period for the sense of self, with results indicating that self-efficacy and body agency were substantially higher than the nulligravida group. Self-efficacy is linked to social support, which may strengthen as family and friends become aware of the pregnancy and bonds are formed with other parents<sup>84</sup>. The improvement of body agency could be linked to a sense of adaptation and appreciation of the physical changes of pregnancy. The second trimester often offers a reprieve from the negative physical symptoms that dominate the first trimester, and uncomfortable or aesthetically worrisome body changes common in later pregnancy, such as lumbar pain, skin pigmentation or varicose veins, are yet to occur<sup>85</sup>. Body Estrangement was significantly higher in the pregnant cohort overall, though the magnitude of differences between the primigravida and nulligravida groups decreased over the course of the pregnancy, which may further reflect a sense of adaptation to the physical changes of pregnancy.

Further, the second-trimester cohort had accuracy comparable to the nulligravida group during the shape-label task, whilst accuracy for the first and third trimesters was significantly poorer. Since this difference was not seen in the self-bias measure and was not an interaction between trimester and identity, this suggests that this reflects differences in learning processes between trimesters that are not specific to the self. This is consistent with previous research finding explicit memory deficits primarily in the third trimester<sup>86</sup>. The first trimester deficits we observed are more surprising given the literature, which generally suggests a decline in cognitive processes such as memory over the course of pregnancy<sup>87</sup>.

Taken together, these results indicate that the self undergoes a dynamic process beginning with disruption in the first trimester, as evidenced by particularly decreased learning about the self (and other associations) and an increased sense of negative agency compared to the other trimesters. The second trimester appears to come with a strengthened sense of self compared to nulligravida participants, the first or third trimester, with increased self-reported self-efficacy, increased body agency which represents feelings of attractiveness, pride, and confidence in one's body as well as recovery of (self-)learning processes to a nulligravida baseline. Finally, the third trimester shows a relative return to the nulligravida baseline in terms of the self-model with strong evidence for a return of the learning deficit and a continuation of body experiences characteristic of pregnancy as a whole.

### Self-concept clarity

Our data provide no evidence for an association between self-concept clarity and pregnancy status, and the exploratory analysis showed no effect of trimester. Whilst negatively perceived social role changes, such as job loss, may negatively impact self-concept clarity<sup>88,89</sup>, transitional experiences that are perceived as positive, growth-promoting and exciting have been associated with increased self-concept clarity, even if stressful<sup>90,91</sup>. As such, our evidence for a lack of differences between groups may reflect heterogeneity in the extent to which pregnant women perceive their role transition as positive. Other studies found that role transitions did not impact self-concept clarity unless there was a perception that the role was a means of achieving specific goals central to their sense of self<sup>92,93</sup>. Therefore, the extent to which pregnancy is related to self-concept clarity may be moderated by accompanying positive or negative emotions and how the experience is framed in terms of life goals.

### Intentional binding

The classic intentional binding effect was not found in our experiment. This is likely due to insufficient trial numbers, thus leading to a noisy signal which made the action and visual condition performance statistically similar. Using an interval reproduction method, as we did, is one of a few common ways of measuring temporal perception for intentional binding; however, there are often 80–100+ trials per condition to detect differences<sup>94,95</sup>. We had only 32 trials per condition. This stands in contrast to Makwana and Srinivasan<sup>32</sup>, who used a numerical report method and 30 trials per identity label (~3× the current study, with three labels) but did not have a no-action condition for contrast. There has been some recent investigation into relations between such methods of measuring temporal perception in intentional binding paradigms, comparing the original Libet clock method with the numerical estimation method, and finding evidence for no correlation between them<sup>96</sup>. Future research should consider reattempting other methods in these groups.

Despite not finding differences between active and visual conditions using this implicit measure of agency, our data suggests an alignment between the judgement of agency in the intentional binding task and the sense of negative agency gathered through self-report. When we excluded participants reporting *no* judgement of agency in either the visual or the agentive condition of the task, results showed evidence *against* group differences for the sense of negative agency. This suggests that these two ways of measuring a lack of agency converged in some participants, driving the group difference in the self-report measure. Often, even intentional binding tasks employ both direct and indirect sense of agency measures, capturing

the interval between an action a participant performs and a subsequent sensory outcome, as well as their subjective judgement of the relationship between their action and the outcome. While there has been some recent scepticism about the correlation between such direct and indirect measures<sup>97,98</sup>, calling into question intentional binding as a marker of agentive experience, other authors have demonstrated intra-individual correlations between self-reported agency and intentional binding in the auditory and visual domains<sup>99</sup>. Correlation between self-reported agency and intentional binding supports the canonical interpretation that temporal compressions in an intentional binding paradigm can be used as a proxy measure of a sense of agency.

### Future directions

The present study adapted Talmon and Ginzburg's<sup>57</sup> Body Experience During Pregnancy Scale to accommodate nulligravida women. The constructs within this scale are multidimensional and reflect complex bodily experiences that various existing measures of body image or body satisfaction fail to capture. However, whilst the elements of body estrangement, such as feelings of invasion and enslavement, may be familiar to a pregnant cohort, such concepts may not be adequately comparable to general population control cohorts. Future research should consider comparing with other groups, including those with eating disorders, individuals with schizophrenia, and postpartum women.

Investigating the sense of self in the postpartum is also an area of great interest and little knowledge, and a similar study to this in the postpartum is gravely needed. Mental illness is higher in women than men (though men are also much less likely to seek support) and even more common in transformative periods, such as the perinatal period and menopause<sup>100,101</sup>. A small number of past studies connect this increased vulnerability to mental illness in the perinatal period to the sense of self. Reich et al.<sup>4</sup> showed that women who associate negatively valued traits to the self and do not identify with 'expectant mother' in the third trimester show the highest depression scores 3–6 months postpartum, which was modulated by maternal identity. Holt et al.<sup>102</sup> showed that poorer self-concept clarity increases the likelihood of experiencing psychotic-like experiences as a new mother and modulates the influence of birth trauma on these experiences. Understanding fluctuations in the self during this transformative experience may unlock a better understanding of perinatal mental illness.

While the present study was open for participation for people of all gender identities, our sample was almost entirely limited to cisgender women, it is important to consider that many non-binary people and transgender men assigned female at birth seek gestational parenthood, and available literature often overlooks their experiences of pregnancy<sup>103</sup>. For instance, whilst body visibility in the present study was comprised of experiences with negative connotations, such as relating to being stared at or evaluated, transgender men have described visibility during pregnancy as 'acts of empowerment' and representative of overcoming barriers to reproductive choice<sup>104</sup>. On the other hand, visibility brings specific challenges, including safety risks and increased exposure to transphobic behaviours<sup>105</sup>.

Given that the present study did not include a multiparous cohort, it is unclear whether results reflect the first-time nature of pregnancy or pregnancy more generally. Thus, future research may compare body experiences across primigravida and multigravida or multiparous cohorts.

Pregnancy provides a unique opportunity to examine how the self-model transitions in response to major physiological changes along with an emerging maternal identity. As pregnancy progresses, new actions, values and beliefs are adopted in preparation for the rigours of parenthood. Our results reflect the complexity of experiences of the self during pregnancy, as manifested by a sense of agency, feelings of body estrangement, and relationship with the surrounding environment in terms of increasing visibility. Our results also provide initial support for trimester effects on multiple measures, suggesting that self-related constructs are influenced by unique physiological and psychological transformations occurring during each stage of pregnancy.

## Data availability

The data presented here were collected, processed and analysed according to preregistration registered in the OSF platform (<https://osf.io/vua52>). The dataset used for statistical analysis and the preprocessing script is freely available as part of the project “Self in Pregnancy—Shape-label matching, Intentional Binding, and Self-Report” on the OSF platform (<https://osf.io/9mhbg/>).

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## Author contributions

K.P. — Conceptualisation, data curation, formal analysis, funding acquisition, investigation, methodology, project administration, supervision, validation, visualisation, writing—original draft, writing—review & editing. R.O. — writing—original draft, writing—review & editing. S.D.J. — Conceptualisation, funding acquisition, methodology, project administration, supervision, writing—review & editing.

## Competing interests

The authors declare no competing interests.

## Additional information

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**Correspondence** and requests for materials should be addressed to Kelsey Perrykkad.

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