Original article

Postpartum depression screening through artificial intelligence: preliminary data through the Talking About algorithm

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Abstract

Postpartum depression (PD) is the most widespread perinatal psychiatric disorder, also representing the most frequent non-obstetric birth-related complication.

From an epidemiological point of view, it has an average prevalence of 17-18% worldwide. This psychiatric disorder may have long-standing effects on the health of both the mother and the child, but also on the relationship with the partner (including paternal PD). Therefore, an early diagnosis is fundamental to treat this disorder immediately and avoid such complications.

Talking About, by the company GPI (Trento, Italy), is a project focused on voice analysis as a medium to access human emotions. It consists of

a series of Speech Emotion Recognition (SER) algorithms. The aim of the study is to evaluate the application of the artificial intelligence (AI) algorithm Talking About on the mothers' emotions analysis. Talking About investigates the unconscious aspects of voice that usually cannot be controlled or voluntarily modified, aiming at identifying the subjects' emotions. Thus, all bias, characterising all classic screening questionnaires, should be neutralised, achieving a sharper overview of the mothers' emotional state.

The mother's emotional results are displayed in 5 main categories: 2 positive, 3 negative.

This study has engaged a total of 154 mothers who gave birth at the "Policlinico Universitario D. Casula" and/or carried out a pediatric examination at the "ambulatorio SOS MAMI" (which is a PostNatal Care Service). They underwent both the Edinburgh Postnatal Depression Scale (EPDS) test and the Talking About voice test.

Despite this study's sample limitations, our preliminary data related to PD symptoms identification are promising and encouraging, leading the way to further investigations related to the application of AI as a PD screening support. Indeed, further studies are needed to improve our knowledge on this topic and possibly apply this tool in clinical practice in the future, even considering PD of the father.

Keywords

Postpartum depression, artificial intelligence, Edinburgh Postnatal Depression Scale, deep learning, Speech Emotion Recognition, Talking About algorithm.

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How to cite

Introduction

Postpartum depression (PD) is the most widespread perinatal psychiatric disorder, also representing the most frequent non-obstetric birth-related complication [1, 2].

The *Diagnostic and Statistical Manual of Mental Disorders – Fifth Edition* (*DSM-5*) [3] defines PD as a major depressive episode specifying its "peripartum debut": a major depressive episode whose onset is during pregnancy or within the first 4 weeks after giving birth. Even the *International Classification of Diseases* (*ICD-10*) [4] does not consider PD an independent disorder but rather a major depressive episode arising within 6 weeks after giving birth. Currently, both definitions are not considered completely correct, as the temporal criterium of 4-6 weeks is thought to be inadequate to describe this form of depression that can occur up to 1 year after birth, with its maximum incidence peak between 1 and 3 months. Nevertheless, some authors argue that onset after the first 6 months post-birth is more likely to be framed as a depression that is not necessarily postpartum. It is evident that these classification differences are testimony to this issue's complexity [1-4].

From an epidemiological point of view, two extensive literature reviews and metanalyses estimated an average prevalence of 17-18% world-wide [5, 6].

In 2021, another extensive and interesting work was published [7], presenting updated epidemiological data. The authors analyzed 556 studies, amounting to a total of 172,342 women coming from 80 different countries: the overall prevalence was determined to be 17.22%, with wide loco-regional variability.

The consequences of this pathology affect the health of both the mother, who will face the impairment of her personal, social and working functioning, and the child, who could have to face altering of its affective, behavioural and social development, but also the relationship with the partner (including paternal PD). Therefore, an early diagnosis appears of fundamental importance to promptly introduce adequate therapy [8, 9].

Talking About, by the company GPI (Trento, Italy), is a project focused on voice analysis as a medium to access human emotions. It consists of a series of Speech Emotion Recognition (SER) algorithms, which is to say deep learning algorithms that, applied to human voice audio

signals, either happening in real-time or priorly recorded, can process the speech and examine the paralinguistic elements to recognise and label the expressed emotions. The goal is to determine the emotional state of the speakers, extracting it from their speech patterns, like prosody, pitch, or rhythm [10-12].

This study's objective is to evaluate the application of the artificial intelligence (AI) algorithm Talking About on the mothers' emotions analysis. Talking About investigates the unconscious aspects of voice that usually cannot be controlled or voluntarily modified, aiming at identifying the subjects' emotions. This study, through the exploitation of these abilities, will analyze the selected mothers' emotions by "listening to their voices". In doing so, all bias, characterising all classic screening questionnaires, should be neutralised, achieving a sharper overview of the mothers' emotional state.

Materials and methods

The Talking About project

The Talking About project articulates through 3 AI agents: "burn-out prevention in employees", "patients' emotions", and "environmental Emotion Recognition (ER)". Each agent is independent and fulfils a specific duty. Currently, only the "patients' emotions" agent has been completed and is in production, while the other 2 are still under development.

Each AI agent has a modular structure formed by various deep learning models working in synergy to carry out a specific job.

In its first phase, the project analyzed audio derived from an "in-house" pilot study. The obtained dataset served as the foundation for each of the 3 AI agents; precisely, the ER deep learning model, based on a Convolutional Neural Network, is inside all of them. Each agent, though, is additionally made up of other deep learning models to obtain specific functions. For example, the "patients' emotions" agent also consists of the Voice Activity Detection (VAD) model [10], while the "burn-out prevention in employees" agent, along with the VAD one, of the Voice Separation (VS) model [11] and the Speech Enhancement (SE) one [12].

The VAD model is based on a Recurrent Neural Network and has been trained to recognize human speech from no-speech (meaning silence, music

or background noise), computing a probability (ranging from 0 for no-speech to 1 for human speech) every 0.5 secs. This is done to be able to apply the ER model only to the speech part. The VS model helps recognise different voices in a stream of more than 1 speaker where audios are mixed. Finally, the SE model produces de-noising of the audio stream, increasing the signal-to-noise ratio, dampening the environmental noise and improving the speech signal.

Thus, each agent follows a specific path made up of different deep learning modules that together represent a SER model capable of extracting emotions from human speech. Empirically, we found out that the most robust ER output is reached in clips of around 6 seconds, with 4 cumulative seconds of speech and 2 of silence, so that is the time resolution with which the model was built.

One of the factors differentiating the different AI agents is their being either "online SER" or "offline SER". The online SER enables the real-time recognition of emotions, and the AI agent must provide a result within 2 seconds of the audio clip ending. The online agents favour speed and use lighter-weight deep learning models to reduce the computational requirements, making them suitable for the application to modern smartphones, too. On the contrary, the offline SER provides slower feedback but enables employing more complex statistical techniques and heavier deep learning models to reach higher accuracy.

The HAUMEA portal

The first step in carrying out the presented study was the creation, by GPI, of an *ad hoc* portal named HAUMEA based on Hawaiian mythology referring to the fertility goddess. The portal can be accessed through a tablet, allowing:
1. the authentication of the authorised personnel;
2. to register the patients by using an alias (a univocal numerical code) to ensure anonymity;
3. the collection of anamnestic information for the subsequent statistical analysis and to highlight potential risk factors related to PD;
4. to perform the Edinburgh Postnatal Depression Scale (EPDS) test, considered to be the gold standard for PD screening [12];
5. the voice analysis delivery through Talking About;
6. the real-time display of both tests' results;
7. a history display of the already carried out tests.

Study's population

This study has engaged a total of 154 mothers who gave birth at the "Policlinico Universitario D. Casula", AOU Cagliari (Cagliari, Sardinia, Italy) and/or carried out a pediatric examination at the "ambulatorio SOS MAMI". The latter is a PostNatal Care (PNC) Service of the "Policlinico Universitario D. Casula" for supporting the infants' breastfeeding and facing minimal pathologies, managed by Professor Angelica Dessì.

Regarding the recruitment at the Department of Obstetrics, 77 mothers were enrolled during regular postpartum check-ups. At the PNC Service, the same number of mothers (77 mothers) was enrolled either while waiting for the pediatric visit or immediately after it. The recruitment of mothers started on the 13th of June of 2022 and ended on the 31st of March of 2023 through 2 different modalities: presence in person or through phone contact.

Mothers' collected data were the following: age, spoken language, level of education, if they were working and their profession, and the presence of risk factors for PD. Pregnancy and birth collected data were the following: parity, first child, twin pregnancy, stressful events occurred during pregnancy, diet and any drug administration, peri-partum complications, and type of birth. Data considered for the newborns were the following: gestational age, weight, type of breastfeeding, and neonatal health.

Each patient who accepted to enter the study signed an informed consent form. In addition, it has been highlighted that the participation was completely voluntary and anonymous.

Tests' delivery

The mothers recruited at the PNC Service completed the tests during the recruiting process.

Instead, the mothers, recruited at the Department of Obstetrics or through phone contact after giving birth, were contacted again, around a month later, to arrange a meeting for the tests' delivery. According to the patient's preference, the meetings were arranged in presence, usually in concomitance with other visits at the "Policlinico Universitario D. Casula", or through video call, allowing for the remote delivery of the tests.

When the tests took place in presence, it was done through a tablet with Internet access to access the HAUMEA portal, following these steps:

1. The operator accesses the HAUMEA portal by using their personal password. Automatically, a univocal 6-digit code is assigned to ensure anonymity. This code allows the operator to access the platform later to review the archived results of the tests. The correspondence between the numerical code and the patient's name is exclusively stored by the office's staff.

2. The second phase is represented by the filing of the medical report, to obtain information about the physio-pathological profile of the women, of the newborn, pregnancy-related data, birth-related ones, risk factors and protective factors for PD and any motivation of the access to the PNC Service (for applicable cases). Some of these pieces of information are selected amongst a series of predefined options, while others provide an open answer. The medical record and the possible answers are reported below. Once the filing is complete, the saving shall be executed by clicking the button at the bottom right. The medical report, along with its related questions, is reported in **Fig. 1** (subject's case history).

3. Once the medical report has been filed, the delivery of the EPDS takes place by accessing its designated section (**Fig. 2**) [13]. Its filing is mainly carried out autonomously by giving the tablet to the mother. Once the filing and saving are completed, the operator can review the obtained score.

4. The last phase is represented by the Talking About voice test. To quicken the test's delivery times, the mother is requested to recount the day with the kid. Once ready, the operator accesses the audio front end and clicks on the purple microphone icon at the top left. The recording ends once the microphone icon turns white. The AI software does not keep a record of the audio recording, as it does not assess the specific verbal content, but rather the voice's characteristics, and it can identify emotions through that. In **Fig. 3** and **Fig. 4**, Talking About screenshots are presented. To reach a deeper analysis, the emotions have been subdivided into categories of negative emotions ("I disagree", "I'm tired", "Feeling blue") and positive ones ("I feel good", "It's a beautiful day"). The most prevalent emotion for each mother has been taken into consideration. Once finished, the operator reviews the result

on a page in the shape of a histogram. By clicking on the bar on top of the histogram, it is possible to view a percentage score for each category:

- "I feel good" (*"Mi sento bene"*);
- "It's a beautiful day" (*"È una bella giornata"*);
- "I disagree" (*"Non sono d'accordo"*);
- "I'm tired" (*"Sono stanca"*);
- "Feeling blue" (*"Vedo tutto nero"*).

5. Once all sections are complete, the operator reports data on an Excel® file to obtain a database for both consulting and elaborating the collected data.

Figure 1. Subject's case history.

Figure 2. Edinburgh Postnatal Depression Scale (EPDS) test.

Figure 3. Talking About screenshot.
[Translation of the screenshot:
Confirm your profile and try to choose an image.
Based on your choice, others will be displayed. Speak for some seconds, telling a similar situation lived by you or another person. Alternatively, generally describe the image.]
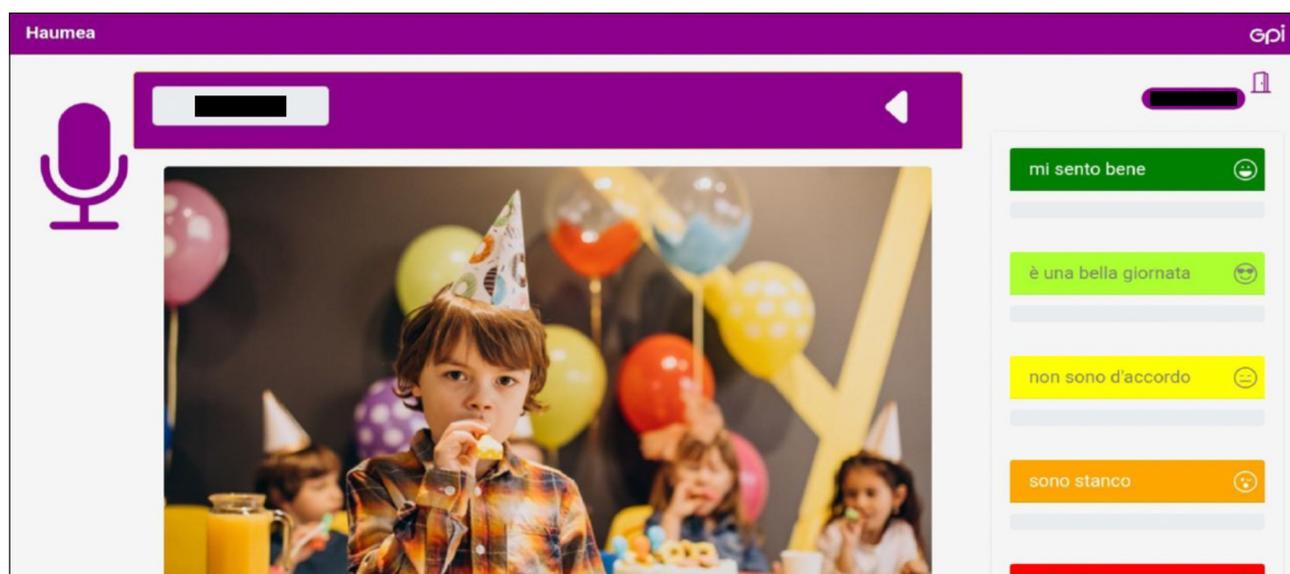
Figure 4. Talking About screenshot.
On the right, the 5 Talking About emotion options are displayed.

Results

Adhesion to the study at the PNC Service was around 95%, while at the Department of Obstetrics it was around 93%. The number of mothers who had at least 2 apart test deliveries (n = 141) that executed the test in personal presence was 72 (51%), while 69 (49%) through video call. The average age of the participants was 34.4 ± 4.4 years (min. 24, max. 49). Most of the women, 75%, were older than 31 when they gave birth. Specifically, the most represented age range (34%) was between 31 and 35 years old. The percentage of foreign women who took part in this survey was 3.84%. The mothers who had been breastfeeding when evaluated were 52%. 44% of the whole population had shown baby blues. Employment data was available for 137 mothers (109 employed and 28 unemployed). Family support data was available for 141 mothers (support network perceived as adequate: 121 mothers; support network perceived as inadequate: 20 mothers).

The sample's EPDS class subdivision is presented in **Fig. 5**. Data analysis was performed through two phases by observing the sample from two different points of view.

Firstly, the EPDS score was evaluated to identify the mothers who showed a score ≥ 9 and ≥ 13, as they have a higher risk of developing PD. The mothers who obtained a score ≥ 13 were compared to the results coming from the emotions detection by the AI system Talking About, after

being subdivided into specific subgroups. To reach a deeper analysis, the emotions have been subdivided into categories of negative emotions ("I disagree", "I'm tired", "Feeling blue") and positive ones ("I feel good", "It's a beautiful day"). The most prevalent emotion for each mother has been taken into consideration. Sample's detected emotion subdivision is presented in **Fig. 6**.

Moreover, the reason for the mothers' access to the PNC Service was analyzed and compared to the EPDS and Talking About. The reasons for access to the PNC Service have been divided into breastfeeding, auxologic check-up, dermatitis, supplementary feeding and "others" (including, one or two for each access case: constipation, papular urticaria, crying spells, cough and fever, and bronchiolitis). Of a total of 77 mothers, 32% accessed for breastfeeding support, 24% for the auxologic check-up, 19% for dermatitis, 13% for supplementary feeding and 10% for other reasons.

Out of the 77 mothers who took part in the studio after being enrolled during the pediatric visit at the PNC Service, 21% of them presented an EPDS score ≥ 9, while out of the 77 mothers enrolled at the Department of Obstetrics of the same hospital facility that amounted to 18%. Considering both groups together, the mothers with EPDS scores ≥ 9 were 19%.

Again, considering both groups together, regarding the positive emotions (correctly detected with minimal follow-up in 141 mothers), data is the following:

- if we consider the mothers' age, positive emotions are more frequent at the extremes of the sample (< 25 and > 40 years old);

- the "I feel good" emotion is quite present (1 mother out of 4) during the first month, but tends to drop during the second and third months, finally going to zero.
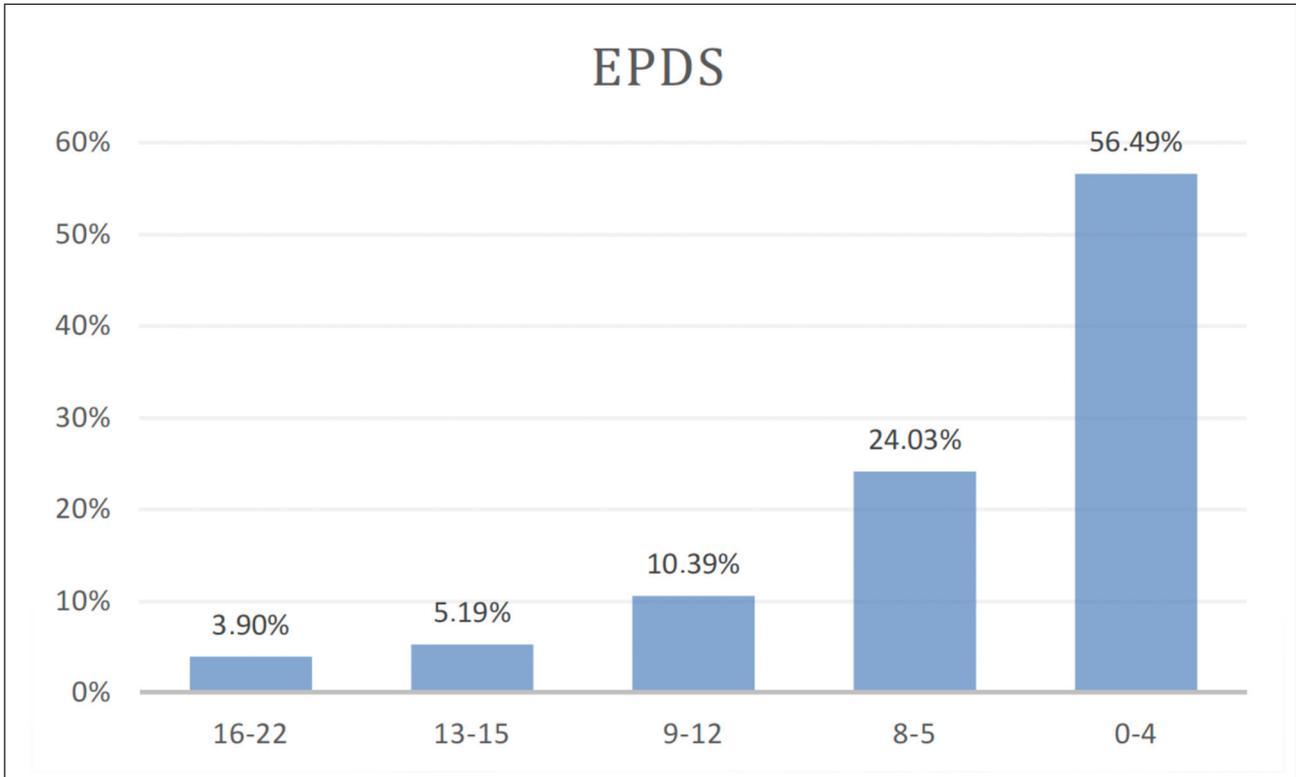
Figure 5. Sample's Edinburgh Postnatal Depression Scale (EPDS) classes subdivision.
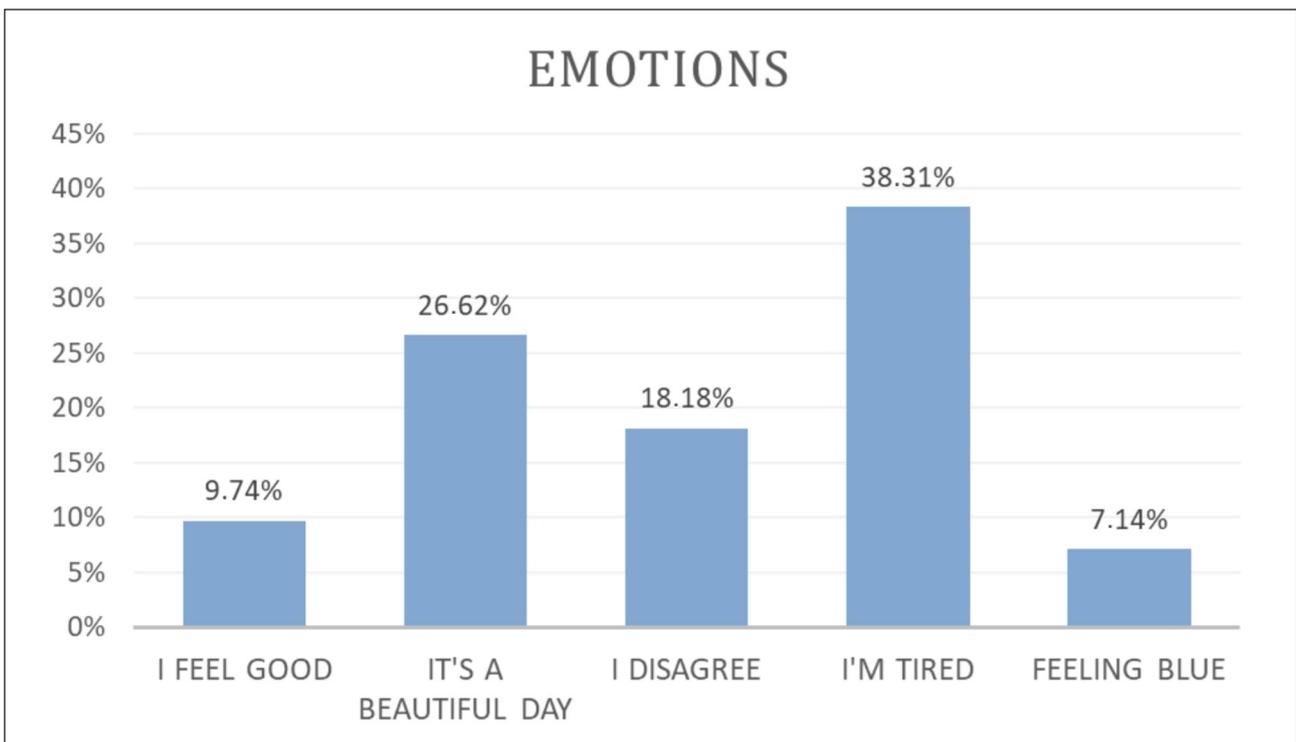
Figure 6. Sample's detected emotion subdivision.

Regarding the negative emotions (correctly detected with minimal follow-up in 141 mothers), they prevail:

- in mothers with low levels of education and unemployed ones;
- in mothers who turn to the PNC Service for problems linked to breastfeeding;
- in mothers who took the test through a video call.

The "I'm tired" emotion is prevalent until 6 months after giving birth, then dropping.

The "Feeling blue" emotion has extremely low values during the first month, getting to characterise 1 mother out of 4 after 6 months.

The subgroup with an EPDS score ≥ 13 showed 78% of negative emotions.

Discussion

We compared our results with those available at national and regional levels. Here, some data will be highlighted.

The average age of the first-time mothers who took part in the study is 33.5 ± 5.2 years (min. 24, max. 49), higher than the national average of 31.6 [14], but in line with the regional trend: in Sardinia, the average age at first birth is 33 years [15].

The data for foreign women who took part in the test (3.84%) appears to be sharply lower than national data, where they contribute to 19.9% of total births [14]; however, it reflects the regional trend, where children born from foreign mothers are 4.4% [1].

Regarding the sociodemographic aspects, like the level of education and employment, notoriously associated with PD risk, this study confirms data from the literature [7]. In fact, in this sample, too, mothers with a lower level of education (third year of middle school) have presented negative emotions (66%) more frequently than positive ones (8%). Distinguishing women between graduated and not graduated, on the contrary, does not show any significant difference.

Regarding employment, even though the two groups present uneven results (available data: 109 employed vs. 28 unemployed), interesting observations can be made when singularly considering each one of the two subgroups. Unemployment was highly linked to a higher frequency of negative emotions: 53% of unemployed women predominantly showed negative emotions, against 22% presenting positive ones. On the contrary, an overlapping frequency between the two

categories emerged among employed mothers: 35% of positive emotions and 37% of negative ones.

Regarding the influence of an adequate support network, there is a deep inhomogeneity in the sample: the number of women who feel to have an adequate support (121 mothers) is 6 times bigger than the number of those who do not feel supported (20 mothers). This data, however, contributes to highlighting how family and, more generally, the community still play a fundamental role in Sardinia in supporting mothers who feel accompanied and advocated for during their motherhood journey.

Regarding the negative emotions that prevail in mothers who turned to the PNC Service for problems linked to breastfeeding, this highlights the well-known relationship between depression and lack of breastfeeding [5, 16-19]. Breastfeeding seems to reduce the incidence of PD; the depression that follows after delivery can lead to premature cessation of breastfeeding, shortening its duration. Prenatal depression also affects breastfeeding, since it generally appears associated with a late onset of breastfeeding. Early breastfeeding is associated with a lower risk of developing PD, while prepartum anxiety and depression levels are strongly related to stopping breastfeeding; early termination of breastfeeding, in turn, is predictive of an increased incidence of PD. This data demonstrates a strong association between the presence of depression and early cessation of breastfeeding [1, 2].

In our study, regarding the data about the health of newborns and PD, we did not find any particular relationship, mainly because the infants were generally healthy and the sample population was limited.

Related to the modality of execution of the test, either in-person or through video call, the sample can be substantially divided in half. This allows us to make meaningful considerations. What one would expect, having a similar number of patients, would be to obtain overlapping results, but discordant ones were reached. During online tests, negative emotions were found more frequently than in in-person tests (in particular, the "I'm tired" emotion [49% vs. 29%]). On the contrary, positive emotions were prevalent in in-person tests compared with online tests (in particular, the "It's a beautiful day" emotion [39% vs. 29%]). This apparent discrepancy can be explained in two different ways. First, in the online modality, each woman has used a device, a microphone, that was different from one mother to

the other, and this could have impacted the voice acquisition quality, turning the group into a highly uneven one compared to in-person counterparts. Every device's microphone, especially the most commercially available ones, will distort the voice on the audio recording in a specific way. This noise, when the same device is used for all the subjects (when the test was delivered in personal presence), tends to annul the results as it is quite consistent through the recordings; something, on the contrary, unachievable with the tests taken through the mothers' devices. Moreover, we cannot deny the chance that, when compared with an ambulatory room, one's own home can have background noise and larger acoustic noise; however, this is only a speculation. Finally, even the mother's choice to take the test through video call instead of in personal presence could hide a possible discomfort towards having to face such a test or having to interact more directly. Another element not to be underestimated is having performed the test without potential conditioning (i.e., their partner or mother's presence at the clinic).

Finally, a concluding remarkable data is the subgroup having an EPDS score ≥ 13 showing 78% of negative emotions, thus suggesting a good overlapping between Talking About and the PD screening test used as the literature gold standard.

Limitations of the study

We must underline that our study presents some limitations. It is a preliminary study involving a relatively low number of mothers, who are divided into 2 different categories. We did not consider mothers who delivered preterm newborns, who present high percentages of PD [20]. Moreover, some Talking About voice tests were registered in presence, others online. To our knowledge, this is the first AI study involving mothers for a screening for PD. These data must be taken into account. Further studies are needed to explore this topic.

Conclusions

PD is the most widespread perinatal psychiatric disorder and represents an actual social problem with negative consequences for the health of the mother herself, the father and the child. There is an increasing interest in the application of AI in this context, to refine patient screening by precisely identifying possible PD predictors and, subsequently, a population at risk of developing the disease, in an effort to lower its morbidity, mortality and economic burden [21, 22]. Variables obtained from sociodemographic and clinical aspects (psychiatric and gynecological factors) seem the most reliable [22].

Our approach is completely different and more personalized: to reliably recognize emotions and/ or stress through the analysis of the human voice (voice recognition test) with the application of a series of AI algorithms to an audio file, which can also be very short (a few seconds), and can be acquired not only in presence, but also remotely, by telephone or via the web.

Despite this study's sample limitations, preliminary data related to PD symptoms identification are promising and encouraging, leading the way to further investigations related to the application of AI as a medium of PD screening support. Further studies in the next future are needed to explore this topic, even considering PD of the father [23, 24].

Declaration of interest

Paolo Ranzi, Ismaela Avellino, Francesca Marinaro, Giovanni Oliverio, Antonio Colangelo are employees of the company GPI (Trento, Italy), which developed the Talking About project. The other Authors have no conflict of interest.

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