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(54) **Title**: SCREENER FOR SLEEP DISORDERED BREATHING

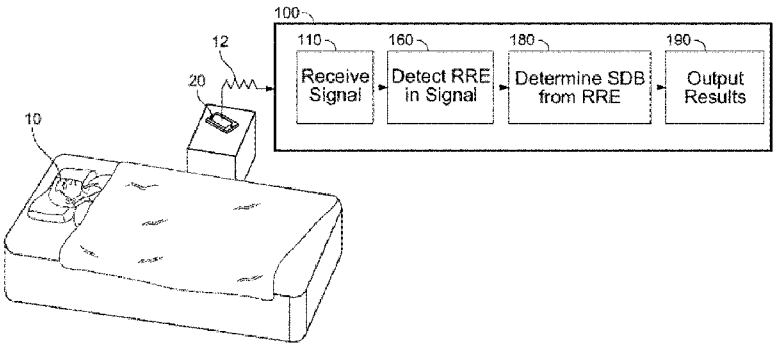

FIG. 2A

(57) **Abstract**: Methods and apparatus detect events of sleep disordered breathing from an input audio signal such as from a sound sensor. A processor may be configured to receive the audio signal that represents sounds of a user during a period of sleep. The processor determines reliable respiration epochs from the audio, such as on a frame- by-frame basis, that include periods of audible breathing and/or snoring. The processor detects presence of a sleep disordered breathing events, such as hypopnea, apnea, apnea snoring or modulated breathing, in the reliable respiration epoch(s) and generates output to indicate the detected event(s). Optionally, the apparatus may serve as a cost-effective screening device such as when implemented as a processor control application for a mobile processing device (e.g., mobile phone or tablet).

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AMENDED CLAIMS
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Article 19 PCT Amended Claims

1. A method for detecting an event of sleep disordered breathing of a user, the method comprising:

receiving, in a processor, an input audio signal representing sounds of the user during a period of sleep;

determining, in the processor, from the received input audio signal, at least one reliable respiration epoch (RRE), wherein a period of an input audio signal is classified as RRE based on whether the period includes a plurality of sections respectively satisfying a start section criteria and a middle section criteria;

detecting, in the processor and based on data in at least one determined RRE, presence of a sleep disordered breathing event; and

outputting, from the processor, an indicator of the detected sleep disordered breathing event.

2. The method of claim 1 wherein each RRE comprises a start section satisfying the start section criteria and an event detection section satisfying the middle section criteria.

3. The method of claim 2 wherein the start section criteria comprises a period of consistent audible breathing .

4. The method of any one of claims 2 to 3, wherein the at least one RRE complies with at least two of the following criteria:

the RRE extends for at least a predetermined amount of time;

the RRE includes at least a predetermined number of respiration cycles during the at least a predetermined amount of time; and

the RRE includes at least a predetermined number of consecutive respiration events during the at least a predetermined amount of time.

5. The method of claim 4, wherein:

the predetermined amount of time is two minutes;

the predetermined number of respiration cycles is six, over the predetermined amount of time of two minutes; and

the predetermined number of consecutive respiration events is three during the predetermined amount of time of two minutes.

6. The method of any one of claims 2 to 5 wherein the middle section criteria comprises a period of consistent audible breathing and at least one of:

a. one or more quiet periods of no audible breathing and of a length shorter than an apnoea event;

b. one or more quiet periods of no audible breathing, the periods being long enough to be classified as an apnoea, but short enough to not be classified as a loss of audible signal event; and

c. a quiet period of no audible breathing that is long enough to be classified as a loss of audible signal event.

7. The method of any one of claims 2 to 6, wherein an event from the event detection section is classified as one of an apnoea event, hypopnea event and periodic breathing event.

8. The method of any one of claims 1 to 7 further comprising classifying an event as apnoea snoring by analysing at least one of audio frequency characteristics, audio level and timing characteristics of a snoring signal, and detecting apnoea snoring characteristics.

9. The method of any one of claims 1 to 8 further comprising classifying an event as recovery breathing by analysing at least one of audio frequency characteristics, audio level and respiratory rate of a breathing signal and detecting recovery breathing characteristics.

10. The method of any one of claims 1 to 9, further comprising analysing the input audio signal to detect a recovery breath after a detected quiet period, to confirm an apnoea event.

11. The method of any one of claims 1 to 10 further comprising determining respiratory rate from detected audible breathing.

12. The method of any one of claims 1 to 11 further comprising analysing the input audio signal to detect an elevated respiration rate after a detected quiet period to confirm an apnoea event.

13. The method of any one of claims 1 to 12, further comprising adjusting, with the processor, a gain control for the input audio signal so as to obtain a desired signal to noise for digital signal processing of the signal.

14. The method of any one of claims 1 to 13 further comprising processing the audio signal over a fixed time interval to produce frequency components of the signal in a number of frequency bins for this time interval.

15. The method of claim 14 further comprising analysing the frequency bins to remove any one or more frequency bins attributable to background sounds including at least one of: speech sounds, air handling equipment sounds, traffic sounds, weather or other background sounds.

16. The method of claim 15, further comprising establishing, with the processor, a background noise level of the input audio signal and establishing, for remaining frequency bins, a noise floor threshold level for this background noise.

17. The method of claim 16, wherein determining a noise floor threshold comprises:

identifying, with the processor, one or more quiet frequency bins; and

setting the noise floor threshold as a function of amplitude of the signal in remaining quiet frequency bins,

wherein the method further comprises utilising only these remaining quiet frequency bands to detect signals.

18. The method of any one of claims 1 to 17, wherein determining at least one reliable respiration epoch comprises characterizing frames of the input audio signal based upon their correspondence with one or more signal types.

19. The method of claim 18, wherein the one or more signal types include audible breathing, snoring, coughing, noise disturbance, speech, quiet and unknown.

20. The method of any one of claim 1 to 19, further comprising determining respiration rate for the determined at least one reliable respiration epoch.

21. The method of any one of claims 1 to 20, wherein a loss of audible signal event is used to mark an end of the RRE, wherein the loss of audible signal event is a period of no audible breathing greater than a predetermined time.

22. The method of any one of claims 1 to 21, further comprising providing a notification of at least one of the following:

one or more identified SDB events;
measurement indices and statistics;
historical data;
snoring time; and
other associated details.

23. Apparatus for detecting an event of sleep disordered breathing of a user, the apparatus comprising:

a sound sensor configured to detect sound proximate to the sensor; and

a processor coupled with the sound sensor, the processor configured to:

receive an input audio signal representing sounds of the user during a period of sleep from the sound sensor;

determine from the received input audio signal, at least one reliable respiration epoch (RRE), wherein a period of an input audio signal is classified as RRE based on whether the period includes a plurality of sections respectively satisfying a start section criteria and a middle section criteria ;

detect, based on data in at least one determined RRE, presence of a sleep disordered breathing event; and

output an indicator of the detected sleep disordered breathing event.

24. The apparatus of claim 23 wherein each RRE comprises a start section satisfying the start section criteria and an event detection section satisfying the middle section criteria.

25. The apparatus of claim 24 wherein the start section criteria comprises a period of consistent audible breathing.

26. The apparatus of any one of claims 24 to 25, wherein the at least one RRE complies with at least two of the following criteria that are evaluated by the processor:

the RRE extends for at least a predetermined amount of time;

the RRE includes at least a predetermined number of respiration cycles during the at least a predetermined amount of time; and

the RRE includes at least a predetermined number of consecutive respiration events during the at least a predetermined amount of time.

27. The apparatus of claim 26, wherein:

the predetermined amount of time is two minutes;

the predetermined number of respiration cycles is six, over the predetermined amount of time of two minutes; and

the predetermined number of consecutive respiration events is three during the predetermined amount of time of two minutes.

28. The apparatus of any one of claims 24 to 27 wherein the middle section criteria comprises a period of consistent audible breathing and at least one of:

a. one or more quiet periods of no audible breathing and of a length shorter than an apnoea event;

b. one or more quiet periods of no audible breathing, the periods being long enough to be classified as an apnoea, but short enough to not be classified as a loss of audible signal event; and

c. a quiet period of no audible breathing that is long enough to be classified as a loss of audible signal event.

29. The apparatus of any one of claims 24 to 28, wherein an event from the event detection section is classified as one of an apnoea event, hypopnea event and periodic breathing event.

30. The apparatus of any one of claims 23 to 29 wherein the processor is further configured to classify an event as apnoea snoring by analysing at least one of audio frequency characteristics, audio level and timing characteristics of a snoring signal, and detecting apnoea snoring characteristics.

31. The apparatus of any one of claims 23 to 30 wherein the processor is further configured to classify an event as recovery breathing by analysing at least one of audio frequency characteristics, audio level and respiratory rate of a breathing signal and detecting recovery breathing characteristics.

32. The apparatus of any one of claims 23 to 31, wherein the processor is further configured to analyse the input audio signal to detect a recovery breath after a detected quiet period, to confirm an apnoea event.

33. The apparatus of any one of claims 23 to 32 wherein the processor is further configured to determine respiratory rate from detected audible breathing.

34. The apparatus of any one of claims 23 to 33 wherein the processor is further configured to analyse the input audio signal to detect an elevated respiration rate after a detected quiet period to confirm an apnoea event.

35. The apparatus of any one of claims 23 to 34, wherein the processor is further configured to adjust a gain control for the input audio signal so as to obtain a desired signal to noise for digital signal processing of the signal.

36. The apparatus of any one of claims 23 to 35 wherein the processor is further configured to process the audio signal over a fixed time interval to produce

frequency components of the signal in a number of frequency bins for this time interval.

37. The apparatus of claim 36 wherein the processor is further configured to analyse the frequency bins to remove any one or more frequency bins attributable to background sounds including at least one of: speech sounds, air handling equipment sounds, traffic sounds, weather, or other background sounds.

38. The apparatus of claim 37, wherein the processor is further configured to establish a background noise level of the input audio signal and establish, for remaining frequency bins, a noise floor threshold level for this background noise.

39. The apparatus of claim 38, wherein to determine a noise floor threshold the processor is configured to:

identify one or more quiet frequency bins; and

set the noise floor threshold as a function of amplitude of the signal in remaining quiet frequency bins,

wherein the processor is further configured to utilise only these remaining quiet frequency bands to detect signals.

40. The apparatus of any one of claims 23 to 39, wherein to determine at least one reliable respiration epoch, the processor is configured to characterize frames of the input audio signal based upon their correspondence with one or more signal types.

41. The apparatus of claim 40, wherein the one or more signal types include audible breathing, snoring, coughing, noise disturbance, speech, quiet and unknown.

42. The apparatus of any one of claim 23 to 41, wherein the processor is further configured to determine respiration rate for the determined at least one reliable respiration epoch.

43. The apparatus of any one of claims 23 to 42, wherein the processor is configured to mark an end of the RRE upon detection a loss of audible signal event is

used to, wherein the loss of audible signal event is a period of no audible breathing greater than a predetermined time.

44. The apparatus of any one of claims 23 to 43, wherein the processor is further configured to generate an output notification of at least one of the following:

one or more identified SDB events;
measurement indices and statistics;
historical data;
snoring time; and
other associated details.

45. A non-transient, computer-readable medium having processor control instructions retrievable therefrom that, when executed by a processing device, cause the processing device to perform a method for detecting an event of sleep disordered breathing as claimed in any one of claims 1 to 22 and 46 to 48.

46. The method of any one of claims 1 to 22 further comprising, in the processor, classifying an event as apnoea snoring by detecting audio level of snoring as it differs from regular snore.

47. The method of any one of claims 1 to 22 and 46 wherein the period of the input audio signal is classified as RRE based on whether a section of the plurality of sections satisfies an end section criteria.

48. The method of claim 47 wherein the end section criteria comprises a period of consistent audible breathing.

49. The apparatus of claims 23 to 44 wherein the processor is further configured to classify an event as apnoea snoring by detecting audio level of snoring as it differs from regular snore.

50. The apparatus of any one of claims 23 to 44 and 49 wherein the period of the input audio signal is classified as RRE based on whether a section of the plurality of sections satisfies an end section criteria.

51. The apparatus of claim 50 wherein the end section criteria comprises a period of consistent audible breathing.