(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
26 December 2019 (26.12.2019)

WIPO | PCT

(10) International Publication Number
WO 2019/245451 A1

(51) International Patent Classification:
A61B 5/0484 (2006.01) *A61B 5/113* (2006.01)

(21) International Application Number:
PCT/SG2018/050302

(22) International Filing Date:
20 June 2018 (20.06.2018)

(25) Filing Language: English

(26) Publication Language: English

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(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK,

(54) Title: SENSING OLFACTORY RESPONSE TO ONE OR MORE SCENTS

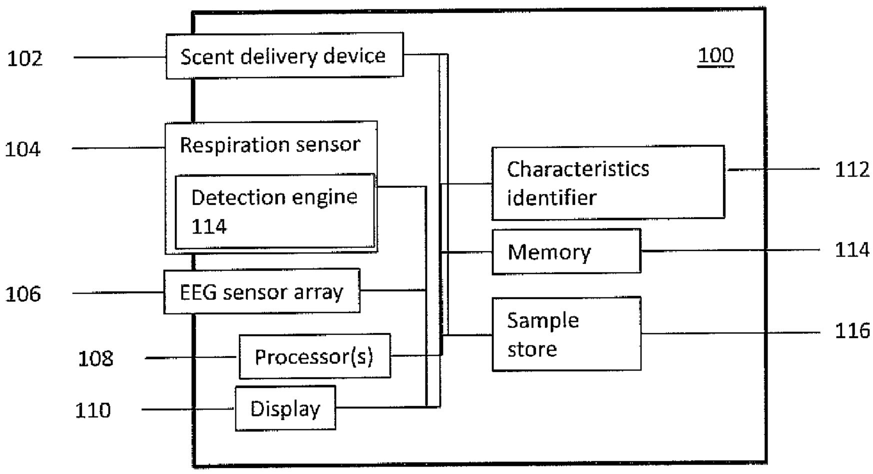

Figure 1

(57) **Abstract:** Disclosed is a system for sensing an olfactory response of a subject to one or more scents. The system comprises a scent delivery device for delivering the one or more scents to the subject, a respiration sensor device for detecting one or more respiratory events of the subject, an electroencephalogram (EEG) sensor array for sensing brain activity of the subject and producing therefrom an EEG signal exhibiting the olfactory response of the subject to the one or more scents, and at least one processor. The at least one processor is configured to compute the one or more respiratory events to determine one or more periods during which the subject may be responding to the one or more scents, derive, from the EEG signal, EEG data corresponding to the one or more respiration cycles of a predetermined time period, and determine the olfactory response of the subject to the one or more scents by comparing the EEG data to model EEG data representing a predetermined olfactory condition of the subject.

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EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:
— *of inventorship (Rule 4.17(iv))*

Published:
— *with international search report (Art. 21(3))*
— *in black and white; the international application as filed contained color or greyscale and is available for download from PATENTSCOPE*

SENSING OLFACTORY RESPONSE TO ONE OR MORE SCENTS

FIELD

[0001] The present disclosure relates to a system and method for sensing an olfactory response of a subject to one or more scents.

BACKGROUND

[0001] Consumer scent preferences play a significant role in some decision-making processes, such as those relating to food, health and wellness products to household products such as cleaning agents.

[0002] Typically, focus groups and market tests are conducted to ascertain consumer response to particular scents, often using questionnaires. Such research is inherently reliant on each consumer's willingness and ability to share their opinions, and those opinions may draw into consideration other factors such as ambient scent, the consumer's mood and rapport with the person conducting the research. In other words, the research is highly subjective and large sample sizes are needed to gain a meaningful diagnosis of consumer preference.

[0003] Some methods exist for using electroencephalogram (EEG) testing to determine consumer scent preference. These methods for identifying scent preference require olfactory meters placed in subjects' nostrils – this is not feasible for marketing related applications and impromptu consumer surveys since consumers will often reject a proposal to have sensors inserted into their nostrils during testing.

[0004] Moreover, in existing scent preference EEG studies there is usually only one pair of pleasant and unpleasant odors involved for the identification. This means a computational model may only be built to capture differences resulting from the consumer perceiving two distinct odours, rather than differences indicating scent preference.

[0005] It is desirable therefore to provide a system and method that enables a more objective acquisition or recognition of scent preference.

SUMMARY

[0006] The present disclosure provides a system for sensing an olfactory response of a subject to one or more scents, comprising:

a scent delivery device for delivering the one or more scents to the subject;

a respiration sensor device for detecting one or more respiratory events of the subject;

an electroencephalogram (EEG) sensor array for sensing brain activity of the subject and producing therefrom an EEG signal exhibiting the olfactory response of the subject to the one or more scents; and

at least one processor,

wherein the at least one processor is configured to:

compute the one or more respiratory events to determine one or more periods during which the subject may be responding to the one or more scents;

derive, from the EEG signal, EEG data corresponding to the one or more respiration cycles of a predetermined time period; and

determine the olfactory response of the subject to the one or more scents by comparing the EEG data to model EEG data representing a predetermined olfactory condition of the subject.

[0007] The at least one processor may be configured to time delivery of the one or more scents, by the scent delivery device, based on the one or more respiratory events. The one or more respiratory events may comprise one or both of an onset of inspiration and an onset of expiration. The at least one processor may be configured to synchronise delivery of the one or more scents, by the scent delivery device, with or based on:

the onset of inspiration; or

the onset of expiration.

[0008] The at least one processor is configured to cause the scent delivery device to commence delivering the one or more scents to the subject over a full respiration cycle, commencing on the onset of expiration.

[0009] The scent delivery device may be configured to deliver a single scent, of the one or more scents, over any particular respiratory cycle.

[0010] The one or more scents may comprise a plurality of scents and the scent delivery device is configured to deliver the scents in either:

random order; or

based on a similarity between successively delivered scents.

[0011] The EEG signal may further exhibit an olfactory condition of the subject when not exposed to any scent of the one or more scents, and wherein the at least one processor is configured to compute the model EEG data from the EEG signal and the respiratory events, the model EEG data derived from brain activity of the subject over one or more inspiration periods during which the subject was not exposed to any scent of the one or more scents. The respiration sensor may be configured to compute a short-term respiratory consistency index (ST-RCI) for specifying a respiratory condition of the subject. The at least one processor may be configured to accept or reject the EEG data based on the respiratory condition of the subject and specified by the ST-RCI. The ST-RCI may be computed according to the formula:

$$\epsilon = \frac{c_1}{N}\sum_{j=1}^{N}\left(t_j - \bar{t}\right)^2 + \frac{c_2}{N}\sum_{j=1}^{N}\left(a_j - \bar{a}\right)^2$$

where N is a number of detected respiratory cycles in a pre-defined time window, t_j and a_j are time and amplitude of detected inhale/exhale points (i.e. peaks and troughs) for a j^{th} respiratory cycle, $\bar{t}$ and $\bar{a}$ are mean time and amplitude over all N detected respiratory cycles, and c_1 and c_2 are coefficients for associating variances in time and amplitude.

[0012] The respiration sensor detects the respiratory events in real-time.

[0013] The EEG data comprises one or more portions of the EEG signal and, where the EEG data comprises two or more portions of the EEG signal those two or more portions are separated by a refractory period.

[0014] The model EEG data comprises one or more characteristics indicating a particular olfactory response is positive or negative, and determining the olfactory response of the subject comprises determining which of the one or more characteristics is exhibited in the EEG data acquired over the one or more inspiration periods of the subject during which the one or more scents were delivered to the subject and thereby determining whether the EEG data is indicative of a positive olfactory response.

[0015] The present disclosure further provides a method for sensing an olfactory response of a subject to one or more scents, comprising:

delivering, by a scent delivery device, the one or more scents to the subject;

detecting, by a respiration sensor device, one or more respiratory events of the subject;

sensing brain activity of the subject using an electroencephalogram (EEG) sensor array and producing therefrom an EEG signal exhibiting the olfactory response of the subject to the one or more scents;

computing the one or more respiratory events to determine one or more periods during which the subject may be responding to the one or more scents;

deriving, from the EEG signal, EEG data corresponding to the one or more periods;

comparing the EEG data to model EEG data representing a predetermined olfactory condition of the subject; and

determining the olfactory response of the subject to the one or more scents.

The method may further comprise timing delivery of the one or more scents, by the scent delivery device, based on the one or more respiratory events. Timing delivery may comprise synchronising delivery of the one or more scents with, or based on, one of the onset of inspiration and the onset of expiration. Delivering the one or more scents to the subject may comprise delivering each scent of the one or more scents over a respective full respiration cycle, commencing on the onset of expiration. The one or more scents may comprise a plurality of scents and delivering the one or more scents to the subject may then comprise delivering the scents in one of a random order and an order based on a similarity between successively delivered scents. The EEG signal may further exhibits an olfactory condition of the subject when not exposed to any scent of the one or more scents, the method then further comprising computing the model EEG data from the EEG signal and the respiratory events, the model EEG data derived from brain activity of the subject over one or more inspiration periods during which the subject was not exposed to any scent of the one or more scents.

BRIEF **DESCRIPTION** OF THE DRAWINGS

[0016] Some embodiments of the present invention will now be described by way of non-limiting example only, with reference to the accompanying drawings in which:

FIG. 1 is a schematic diagram of a system for sensing an olfactory response of a subject to one or more scents, in accordance with the present invention;

FIG. 2 illustrates a method for sensing an olfactory response of a subject to one or more scents, that may be implemented by the system of FIG. 1;

FIG. 3 is a timing diagram showing the timing of events such as scent delivery, with reference to the respiratory cycle of a subject to whom the scent(s) is/are to be delivered;

FIG. 4 is a flowchart of a method for sensing an olfactory response of a subject to one or more scents, in accordance with the present invention;

FIG. 5 provides experimental results of the accuracy of the present methods when compared with the accuracy achieved by sensory methods employing a single EEG bands;

FIG. 6 is a flowchart of a further method for sensing an olfactory response of a subject to one or more scents, in accordance with the present invention;

FIG. 7 is a flowchart of computational steps for an online system for EEG-based scent preference identification;

FIG. 8 is a schematic diagram showing components of an exemplary mobile computing device; and

FIG. 9 shows a system for sensing an olfactory response of a subject to one or more scents, in a condition of use.

DETAILED DESCRIPTION

[0017] A subject's response to the presence of a scent will change dramatically depending on respiratory condition, such as whether a subject is inspirating (inhaling), expirating (exhaling), coughing and so forth. Consequently, respiratory condition is a confounding factor in respiratory as well as sensory motor activities in the brain. The efficacy of existing EEG-based methods of detecting olfactory stimulation is therefore greatly impacted by the respiratory condition of the subject and variations in that respiratory condition.

[0018] In the following discussion, a scent may be a collection or combination of one or more ingredients – e.g. aromatic ingredients, each of which itself may be considered a 'scent' – or may, depending on the context in which the term 'scent' is used, be ambient conditions such as when no particular ingredients are delivered to the subject. The subject's olfactory response to the absence of a scent – i.e. ambient conditions or an 'at rest' state – may be compared to the subject's response when a particular collection or combination of ingredients is delivered.

[0019] FIG. 1 shows a system 100 for sensing an olfactory response of a subject to one or more scents. The system 100 may be portable, to facilitate market testing of olfactory response to various scents without requiring subjects to visit a fixed testing site.

[0020] The system 100 derives EEG data corresponding to particular respiratory events – e.g. periods during which the subject is inspirating – in order to assess the subject's response to the one or more scents. In other words, the system 100 provides for respiratory sensing and synchronised olfactory stimulation. Since the EEG data is derived for periods during which the subject is inhaling, during inhalation of a scent changes in olfactory response – e.g. when compared with a baseline or model (EEG response or EEG data when no scent is delivered) – are more reliably attributable to the presence of that scent when compared with sampling EEG data without reference to the subject's respiratory condition.

[0021] In addition, when comparing the subject's response to different scents, the EEG data is taken while the subject is in a common respiratory condition. For example, the EEG data is collected, for each scent, over a respective period of inspiration. The EEG data exhibiting the subject's olfactory response to one scent can therefore be compared, under the same or similar respiratory conditions, to the subject's response to a different scent. Thus the confounding effect of respiratory condition on the EEG data is substantially removed. Moreover, using the short-term respiratory consistency index (ST-RCI) discussed below, the system 100 (or an operator of that system) can determine whether to accept or reject results of a particular olfactory stimulation test using a scent, depending on the respiratory condition of the subject.

[0022] The system 100 broadly comprises:

a scent delivery device 102;

a respiration sensor 104;

an EEG sensor array 106; and

one or more processors 108.

[0023] The system may further comprise:

a display 110;

a characteristics identifier 112;

memory 114; and

a sample store 116.

[0024] With reference to both FIGs. 1 and 2, the scent delivery device 102 delivers each scent, of the one or more scents, to the subject per step 202 of method 200. The respiration sensor device 104 senses a respiratory cycle of the subject – step 204. This can be done by sensing respiratory events, such as inhalation and exhalation, e.g. by measuring the relative expansion and contraction of the subject's chest and/or abdomen. In practice, the respiration sensor will generally produce a respiration signal corresponding to the respiratory cycle – step 206 – from which artefacts can be extracted such as the onset of inspiration and/or expiration (i.e. respiratory events) – thus the system 100, and corresponding methods, relate to state-dependent olfactory stimulation. The EEG sensor array 106, which may comprise one or more EEG sensors positioned on the head of the subject, senses brain activity of the subject – step 208. The EEG sensor array 106 produces, from the sensed brain activity, an EEG signal exhibiting the olfactory response of the subject to the one or more scents – step 210. The at least one processor, which will herein be interchangeably referred to as the processor though the skilled person will appreciate that multiple collocated or distributed processors may be used without stepping outside the scope of the present disclosure, then computes (e.g. analyses) the one or more respiratory events detected by the respiration sensor 104, to determine one or more periods during which the subject may be responding to the one or more scents – step 212. These periods will typically be inspiration periods, being periods during which the one or more scents were delivered to the subject. The processor then derives, from the EEG signal, EEG data corresponding to the one or more periods and thus corresponding to periods during which the subject can reasonably be expected to be responding to the presence of the scent(s) – step 214. The processor 108 then compares the EEG data to model EEG data that represents a predetermined olfactory condition of the subject – step 216 – and determines the olfactory response of the subject to the one or more scents – step 218.

[0025] The scent delivery device 102 may be any suitable device such as an electronically controlled fragrance dispenser or other smell sample dispenser or olfactometer. The scent delivery device 102 is connected to a scent sample store 116 in which at least one scent is stored for delivery to the subject. An operator may prepare multiple scents and store them in the store 116 for successive delivery, or may prepare each scent in succession for immediate delivery.

[0026] Delivery of scent using the scent delivery device 102 is controlled via the at least one processor 108. In particular, the scent delivery device 102 may comprise a processor of the at least one processor 108 such that it controls itself for the delivery of scent based on timing signals derived from the respiration signal/respiratory events generated by the respiration sensor device 104.

[0027] The scent delivery device 102 may be mounted in a position to direct scent towards the nose of the subject. The scent delivery device 102 may, for example, comprise a scent delivery platform secured in position in the vicinity of the subject's face as shown in FIG. 9. Various other configurations may be used such that the scent delivery device 102 is positioned to deliver the one or more scents to atmosphere around the subject's nose, such that the one or more scents are drawn into the subject's nose during respiration.

[0028] The scent delivery device 102 is controlled by the processor 108. To this end, the processor 108 is configured to time delivery of the one or more scents, by the scent delivery device 102, based features of the respiration signal. Such features may be one or both of the onset of inspiration and/or the onset of expiration (i.e. respiratory events). Notably, delivery may be timed based on one feature (which will interchangeably be called an "event") of the respiration signal, or multiple such features.

[0029] Regarding timing based on a single feature of the respiration signal, delivery of the one or more scents can be synchronised, for example, with the onset of inspiration or the onset of expiration. In this case, each scent may be delivered in a single burst, for a predetermined period of time or over a full respiration cycle. A full respiration cycle is the period between peaks, or troughs, of neighbouring waveforms of respiration signal 304 in FIG. 3 and commencing on the respective peak or trough – i.e. commencing on the onset of inspiration or expiration. The peaks in respiration signal 304 represent the onset of inspiration and the troughs represent the onset of expiration. To this end, synchronising delivery means timing delivery based on another signal, which may include delivering immediately on identification of an artefact in the respiration signal – e.g. concurrently with detection of the onset of inspiration and/or expiration – or after a predetermined delay – e.g. after a predetermined time interval after identification of the onset of expiration.

[0030] Regarding timing based on two or more features of the respiration signal, delivery of the one or more scents can be synchronised, for example, with one of the onset of inspiration and the onset of expiration and end on the other of the onset of inspiration and the onset of expiration.

[0031] The delivery of a scent may, in any case, be automatically synchronised with the respiratory cycle, by the processor 108.

[0032] To ensure an accurate correlation between the EEG data and the scents delivered to the subject, the scent delivery device 102 is configured to deliver a single scent over any particular respiratory cycle. Accordingly, where multiple scents are delivered to the subject, they will typically be delivered over different respiratory cycles. Moreover, the scents will typically be delivered over non-neighbouring or non-successive respiratory cycles to allow the subject's olfactory system to recover or neutralise between scents. As such, the EEG data comprises one or more portions of the EEG signal – one portion in cases where a single scent is used, and one or more than one portion where multiple scents are used – and, where the EEG data comprises two or more portions of the EEG signal those two or more portions are separated by a refractory period – i.e. a period of time sufficient for the subject's olfactory system to return to the baseline condition. The period of time may be predetermined, or may be determined based on the EEG signal once the EEG signal demonstrates the subject's olfactory response has returned to its baseline state.

[0033] One of the significant advantages of the system 100, is that it can be used to assess the subject's olfactory response to multiple scents based on common respiratory conditions. Thus, where multiple scents are delivered to the subject the scent delivery device 102 can be configured to deliver the scents in random order.

[0034] In other cases, the scent delivery device 102 may be configured to delivered scents in pseudo-random order or in a predefined order. The predefined order may be based on a similarity between successively delivered scents. For example, where, of a plurality of scents, two scents are mostly composed of common aromatic ingredients, the may be delivered in succession. Alternatively, to provide greatest distinction between olfactory response to different scents, successive scents may be selected for delivery based on the least commonality of ingredients. In either case, the scents are delivered in an order based on their similarities, which also infers their dissimilarities.

[0035] With reference to FIG. 3, the processor 108 is configured to identify particular features, or respiratory events, from the respiratory signal. In this regard, FIG. 3 is a timing diagram 300 illustrating the respiration signal 302 and operation of the system 100 based on that signal 302.

[0036] Signal 304 is a respiration signal showing periods of inspiration and expiration measured by the respiratory sensor device 104. The peaks, indicated with numeral 304, represent the time of the onset of inspiration and the troughs, indicated with numeral 306, represent the time of the onset of expiration.

[0037] The respiration sensor 104 may operate by:

- buffering received blocks or samples – e.g. a sequence of samples taken over a period of time;
- pre-processing to monitor the condition of the respiratory sensor 104 – this enables detection and rejection of artefacts on the signal that do not reflect relevant respiratory artefacts such as expiration and inspiration, to ensure that only proper breathing signals are used in subsequent stages of processing;
- filtering using a low-latency, adaptive band-pass filter for retaining only breathing-related frequency range measurements (e.g. [0.1 0.3]Hz), thereby reducing noise in irrelevant frequency ranges; and
- setting a refractory time range or refractory period for the last detected event, thereby reducing false positives in event detection and improving system robustness – e.g. setting a predetermined time period from the last detected event (e.g. removal of stimulus) before a new stimulus is applied.

[0038] The respiratory sensor device 104 comprises a respiration detection engine 114 for detecting artefacts present in the respiration signal 302. The artefacts are presently limited to the onset of inspiration and the onset of expiration, but may also include periods during which the subject is holding their breath (i.e. no inspiration or expiration) and periods during which the subject is coughing or experiencing some other respiratory condition during which it would not be advantageous to record and analyse EEG data.

[0039] The peaks and troughs, representative of inhalation and exhalation respectively, are made more robust by comparing the peaks and troughs to previously recorded peaks and troughs to ensure the relevant peak or trough is in fact a true maximum/minimum exhale/inhale point in the respiration signal 304. Target ranges for peaks and troughs may also be set to ensure the actual peaks and troughs are recognised as such, when they are within a predetermined threshold (e.g. within 10%) of a previous peak or trough.

[0040] As mentioned above, the respiratory condition of the subject is critical to ensuring the accuracy of identification of the subject's olfactory response to stimulus, and differences in that response between different stimuli. The process 108, based on the respiration signal 304, therefore calculates a short-term respiratory consistency index (ST-RCI) for detected points or artefacts (i.e. respiratory events) on the respiratory signal 304. The ST-RCI is calculated for *N* detected respiratory cycles in a pre-defined time window for a test trial according to the formula:

$$\epsilon = \frac{c_1}{N}\sum_{j=1}^{N}(t_j - \bar{t})^2 + \frac{c_2}{N}\sum_{j=1}^{N}(a_j - \bar{a})^2$$

where t_j and a_j are the time and amplitude of detected inhale/exhale points (i.e. peaks and troughs) for the j^{th} respiratory cycle, $\bar{t}$ and $\bar{a}$ are the mean time and amplitude over all *N* detected respiratory cycles, c_1 and c_2 are coefficients for associating variances in time and amplitude, and can be empirically set through optimisation towards the best EEG classification outcome.

[0041] The ST-RCI can be used to normalise respiratory cycle variance of EEG measurements. Using the ST-RCI the processor 108 can determine whether the subject's respiratory condition during stimulation was conducive to an accurate olfactory response to the stimulus, or whether the response should be considered indeterminate or unreliable. On this basis, the processor 108 can automatically accept or reject the result of the test or stimulation – e.g. where the variation in timing between inspiration and expiration, or expiration and inspiration, differs by more than a predetermined value from normal as determined by the ST-RCI.

[0042] The artefacts identified by respiration detection engine 114 are indicated on timing diagram 310. The processor 108 is configured to identify, from the respiration signal 304, one or more periods (hereinafter assumed to be inspiration periods) of the subject during which the subject was not exposed to any scent of the one or more scents. With reference to FIG. 3, such a period may be the "rest (trial-trial) interval" 314 between successive trials (i.e. periods during which a scent is delivered to the subject and the subject's olfactory response is measured), the refractory period or may occur before or after delivery of any scent(s) to the subject. A "trial ready" state 318 may thus continue or persist over the full period of the trial – i.e. the trial toggles between a trial ready state 318 and a rest state 314.

[0043] The periods during which EEG data is acquired while the subject is in a rest state – i.e. no scent is being delivered or responded to – may be periods of the same olfactory condition as those in respect of which EEG data is collected during scent delivery and response. Presently, such periods would be periods of inspiration.

[0044] The EEG data for periods over which no scent was delivered may then be used as a comparator for the EEG data relating to intervals over which scent was delivered to the subject. The former therefore forms a model to identify differences in EEG data attributable to the subject's response to each particular scent. The EEG signal thus further exhibits an olfactory condition of the subject when not exposed to any scent of the one or more scents. The process 108 is thus configured to compute the model EEG data from the EEG signal and the respiratory events measured by the respiration sensor 104.

[0045] The system control engine 312, implemented by the one or more processors 108, provides a confirmation message 316 to a processor or operator. The confirmation message 316 confirms completion of a trial and thereby triggers analysis of the result of the trial to determine whether the result should be accepted or rejected. The system control engine 312 also counts the number of trials undergone by the subject. This can be advantageous where a particular scent is delivered multiple times to determine whether the subject's response varies over time or with repeated exposure, or to average the subject's response to multiple samples of the same scent, thereby increasing confidence in the accuracy of the EEG data in representing the subject's olfactory response to that scent. The EEG data and/or model EEG data may thus be acquired over one or more tests (i.e. a single test or more than one test) for each scent or all scents collectively or, particularly in the case of the model EEG data, one or more periods over which the subject was not exposed to any relevant scent.

[0046] The characteristics identifier 112 is configured to identify one or more EEG characteristics in the EEG data acquired over the one or more inspiration periods during which the scent(s) were delivered to the subject. Those characteristics will generally be differences between the subject's olfactory response – e.g. temporal response or spatial response – to the absence of scent when compared with the olfactory response while the subject is exposed to a scent. In some cases, the characteristics will also include notable similarities – for example, where a subject does not respond to a particular scent. A lack of olfactory response to a scent can be useful for products in respect of which olfactory irritation is being tested, or where noticeable odour is undesirable – e.g. in insect repellents.

[0047] The one or more EEG characteristics may be compared to a set of one or more known EEG characteristics, stored in memory 114, indicative of a subject's scent preference – e.g. positive (like) or negative (dislike) response to the presence of a particular scent. The processor 108 may therefore identify whether the subject finds the scent pleasurable or unpleasant, by identifying those particular characteristics in the EEG data. For successive tests with the same or different scents, the EEG data may be stored in memory 114 for relative comparison of EEG data between tests or offline data analysis.

[0048] Particularly with reference to the EEG characteristics, the EEG data measured over periods during which the subject was exposed to a scent may be compared to model EEG data derived from a pool of subjects responding to that particular scent or responding in a predetermined manner to any particular scent. For example, a positive response of a pool of subjects to a particular scent may result in the presence of particular characteristics in EEG data for those subjects, during delivery of the particular scent. If comparable particular characteristics present themselves in the EEG data for the subject in question during delivery of a scent to the subject, it may be determined that the subject's response to the scent was positive. The same may apply for a negative response to a scent. Thus the EEG signal may not, in these circumstances, comprise differentiating characteristics for periods from which the model EEG data was collected.

[0049] A trial may be run on a single scent. In such cases, EEG data for a rest state of the subject will typically be used for the identification of olfactory response. In general, however, it is envisaged that multiple scents will be delivered to the subject over various respiratory cycles.

[0050] The EEG sensor array 106 may take EEG measurements of brain activity of the patient only during periods of, for example, inspiration. Alternatively, the EEG sensor array

106 may continuously take EEG measurements of brain activity and the processor 108 then extracts EEG data for the periods of interest – e.g. inspiration periods over which a scent was delivered to the subject, or inspiration periods while the subject was at rest. Sensing activity of the EEG sensor array 106, or analysis of the EEG signal produced by that array 106, may therefore be synchronised with the scent delivery device 102 or the respiratory cycle so that sensing/analysis is phase-locked to inspiration events. For example, sensing/analysis may:

- commence on detection of the onset of inspiration and cease on detection of the onset of expiration;
- commence on detection of the onset of inspiration and cease a predetermined time period after detection of the onset of expiration and/or after a predetermined number of respiration cycles, inspiration events or expiration events – this is to account for residual stimulation by the scent that extends to a longer period of time than the inspiration period; or
- commence on detection of the onset of inspiration and cease once an 'at rest' or neutral response is detected on the EGG signal.

[0051] The EEG sensory array 106 comprises one or more EEG sensors for detecting brain activity of the subject. The EEG sensor array may also comprise an amplification and/or digitization circuit for converting brain activity (i.e. electrical potentials) into digitized signals. The EEG sensor array 106, or the processor 108, may also receive information on the condition of the process (e.g. readiness of the subject for receipt of stimulus) to enable controlled capture of EEG data – e.g. based on whether the subject in inspirating.

[0052] In all of the above embodiments, the EEG data considered for assessing a subject's olfactory response is taken during common respiratory conditions. Notably, EEG data for periods of inspiration may be accepted for analysis, Similarly, EEG data for periods of expiration may be disregarded.

[0053] In the above embodiments, scent recognition/delivery is dependent on the state of the subject – i.e. whether or not the subject is inspirating or expirating. To ensure the subject is responding to the desired scent, the system 100 may deliver a scent to the subject at a time at, or immediately/shortly before, commencement of inspiration as indicated by the respiration signal 304. Thus the scent is delivered at a time at which the subject is likely to respond to the scent, rather than randomly – e.g. without regard to whether a subject is expirating which would otherwise result in potentially no reaction to the scent. Scent delivery may also be synchronised with, or based on (e.g. a predetermined period after or before), a particular event such as expiration or inspiration.

[0054] The respiration sensor 104 is therefore critical to implementation of methods requiring synchronisation of scent delivery or EEG data analysis based on respiratory condition of the subject. The respiration sensor 104 may measure relative expansion or contraction of the abdomen or chest of the subject during breathing cycles, and transduce that movement into electrical potential (voltage) that can be amplified and digitized.

[0055] FIG. 2 shows a method 200 for sensing an olfactory response of a subject to one or more scents. The method 200 may be implemented by system 100. Presently, the method broadly comprises:

Step 202: delivering the one or more scents to the subject using the scent delivery device 102 – the device 102 may comprise one or more devices;

Step 204: sensing, by the respiration sensor device 104, respiratory events of the subject;

Step 206: producing a respiration signal corresponding to the respiratory events – this may be performed by the respiration sensor device 104 – which may comprise one or more devices – or the processor 108;

Step 208: sensing brain activity of the subject using an electroencephalogram (EEG) sensor array 106;

Step 210: producing, from the sensed brain activity, an EEG signal exhibiting the olfactory response of the subject to the one or more scents – this may also be performed by the sensory array 106;

Step 212: identifying from the respiration signal one or more periods during which the one or more scents were delivered to the subject;

Step 214: deriving, from the EEG signal, EEG data corresponding to the one or more periods – e.g. respiration cycles or a predetermined time period;

Step 216: compare the EEG data to model EEG data, to determine the olfactory response.

[0056] The model EEG data may be EEG data acquired during one or more inspiration periods of the subject during which the subject was not exposed to any scent of the one or more scents. Thereafter, the processor may identify – at step 216 – a difference between:

EEG data acquired over the one or more inspiration periods of the subject during which the one or more scents were delivered to the subject; and

EEG data acquired over the one or more inspiration periods of the subject during which the subject was not exposed to any scent of the one or more scents,

and thereby determine – at step 218 – the olfactory response of the subject to the one or more scents.

[0057] The olfactory response is essentially a change in the EEG data attributable to the response of the olfactory system of the subject to the presence of a scent. From characteristics of the EEG data, it can then be identified whether the subject's response was pleasurable or positive, or unpleasant or negative. The result – e.g. whether the response was positive or negative, and/or the extent to which the response was positive or negative based on the magnitude/amplitude of the response as reflected in the EEG data – or the relevant EEG characteristics themselves may then be displayed on display 110 per step 220. Thus the characteristics are indicative of a particular type of response.

[0058] An operator may also use the display 110 as a graphical user interface (GUI) for controlling the method 200 – e.g. preparing samples of scents and scheduling them for delivery to the subject – and analysing the result such as indications of the subject's positive, negative or neutral response to each scent.

[0059] The method 200, and/or any variations or additions reflected in the descriptions of FIGs. 4, 7 and 7, may be embodied on a non-transitory computer-readable storage medium. In particular that medium, which may equate to memory 114, may have instructions stored thereon that, when executed by the system 100, cause the system 100 to execute the method 200, 400, 600, 700. This extends to a software development kit (SDK) comprising code and command libraries and other features for facilitating performance of the methods 200, 400, 600, 700.

[0060] FIG. 4 schematically represents a method 400 for sensing an olfactory response of a subject to one or more scents. The method 400 takes a human subject 402, and prepares the subject 404 for delivery of scent and measurement of EEG – e.g. by positioning the scent delivery device 102 to deliver scent to the nose of the subject, and positioning the EEG sensor array – which may comprise one or more sensors – on the head of the subject. The subject 402 naturally and continuously undergoes a sequence of respiratory cycles comprising alternate inspirations 406 and expirations 408. The subject 402 will usually be seated comfortably as shown in FIG. 9, with EEG sensor array 904 attached to the head or scalp, a respiration sensory device 906 positioned about the abdomen of the subject 402, an EEG amplifier 908 (forming part of the EEG sensor array 904 or processor 108) for amplifying the EEG signal for analysis, and a display or control panel 910 for visually representing the subject's olfactory response.

[0061] According to the process control 410 as implemented by processor 108, a stimulus (i.e. scent) is assigned or a next stimulus is assigned where one or more scents have been previously delivered to the subject – 412. A sample of the stimulus is prepared – step 414 – and, once prepared, the system 200 is ready for the next trial – step 416.

[0062] To ensure stimulus is available to the olfactory system of the subject at times at which the subject can respond to that stimulus – e.g. when the subject is inspirating – the process control 410 awaits for the trial to be ready – step 418. This involves awaiting both readiness of the stimulus for delivery, and also readiness of the subject to receive that stimulus. Awaiting readiness of the subject may include awaiting elapse of a predetermined period of time from a previous trial, the time being determined based on the time taken for the subject's olfactory system to recover from responding to a previously administered or delivered stimulus.

[0063] Once ready, the system 200 starts monitoring for inspiration onset and/or expiration onset as reflected in the respiration signal 304 – step 420. The scent delivery device 102 awaits expiration onset – step 422 – and, upon detection of the onset of expiration – step 424 – delivers the stimulus to the subject – step 426.

[0064] After delivery of the stimulus, the system 200 awaits detection of inspiration – step 428 – and marks the start of the trial – step 430. The start of the trial indicates the start of the period over which relevant EEG data is collected.

[0065] The process control 410 then awaits a predetermined trial interval – step 432 – before ending the trial – step 434. The trial may end based on a fixed time interval. For example, the trial may end after 2 seconds, or after a period over which the olfactory response of the subject is expected to fade due to the subject's olfactory system becoming accustomed to a particular scent. The trial may instead end based on an artefact identified in the respiration signal 304 – e.g. detection of the next onset of expiration or inspiration following commencement of the trial.

[0066] Upon completion of the trial, the stimulus is removed – step 436. The processor 108 then determines whether to accept or discard the trial – step 438. The trial may be disregarded if, for example, the subject coughs or performs/experiences some other disruptive mental or physical activity, or the trial was otherwise inconclusive, and may otherwise accept the trial (i.e. accept the EEG data is indicative of the subject's response to the stimulus).

[0067] An operator may control the process 400 by selecting stimuli according to a randomly generated stimuli sequence, and triggering presentation of the stimuli to the subject as instructed by the respiration sensor device 104.

[0068] FIG. 5 illustrates a test trial involving a pre-recorded data set taken from a smell test of one or multiple human subjects. A computing algorithm was built to process the EEG data and identify relevant neurophysiological features in association with a given characteristics of the delivered smell(s). The algorithm was adapted based on Filter-bank common spatial pattern technique (FBCSP).

[0069] The experiment involved 9 healthy subjects. Each subject contributed two session of data collection in which various odours were delivered to the subject and odour perception EEG was measured, with the exception of subject 7 whose breathing sensor broke during the experiment.

[0070] This provided a baseline or model against which the EEG data collected during the trial could be compared to identify whether, based on characteristics of the EEG data, the subject found the respective stimulus to have a pleasing or unpleasing odour.

[0071] The stimuli subsequently used during the trial were different to those used to form the baseline or model. This enabled the algorithm to capture EEG patterns (i.e. characteristics) reflecting preference differences that are common to different odours.

[0072] FIG. 5 shows the results of the trial, benchmarked against other algorithms. Particularly, the trial performed in accordance with the method 200, labelled SSP in FIG. 5, was compared to the band-power for each single EEG band. The present methods achieved an average accuracy of around 60%, which outperformed each of the single EEG bands.

[0073] FIG. 6 schematically represents a method 600, similar to method 400, for sensing an olfactory response of a subject to one or more scents. Steps 602 to 608 are substantially the same as steps 402 to 408 and will not be reiterated.

[0074] In this embodiment an operator 610 uses a user interface 612 to select stimuli for presentation to the subject according to a randomly generated stimuli sequence – step 614. The operator then prepares the samples of the scents – by, e.g., placing them in the sample store 116 – per step 616 for delivery via scent delivery device 102.

[0075] Steps 618 to 634 are substantially similar to steps 416 to 432 respectively, with the exception that the trial starts at step 632 upon both stimuli presentation at steps 628 and initial inspiration detection at step 630.

[0076] On completion of the trial at 636 the process 600 identifies the next randomly assigned stimulus per step 614, awaits preparation of the next sample by the operator per step 616, and removes (i.e. stops delivering) the current stimulus – step 638.

[0077] Again, the data produced by the EEG sensor array 106 is either accepted or discarded per step 640 which is substantially the same as step 438.

[0078] FIG. 7 shows a workflow 700 for EEG-based scent preference identification, particularly setting up a preference model. The workflow 700 may be performed in an online context, or a real-time context. The initial setup involves a subject 702 performing some tests by smelling a set of scents and providing – e.g. verbally – information on their scent preferences – test data 703.

[0079] For scent delivery, as the subject 702 respires – step 704 –respiration is detected at step 706. Respiration detection will be achieved using a respiration sensor – e.g. sensor 104. As described with reference to steps 204 and 206, the respiratory cycle of the subject is detected so that EEG data for each scent in the test set of scents is acquired during the same, or substantially the same, respiratory conditions of the subject.

[0080] Detection of respiration causes a stimulation switch to activate – step 708 – thereby triggering delivery of an olfactory stimulus or scent (from the test set of scents) to the subject 700 – step 710. EEG data is acquired – step 712 – and recorded – step 714.

[0081] The training data – EEG data acquired during stimulation of the subject's olfactory system using the test set of scents – is produced at step 716 and EEG data is extracted for periods over common respiratory conditions for each scent, as determined with reference to the sensed respiratory cycle or respiratory events. Typically the periods will correspond to inspiration periods. Thus, preferences to particular scents can be synchronised and patterns extracted – step 718. To ensure extracted patterns are robust (i.e. can be confidently considered to relate to a particular scent preference) the test set of scents may each be delivered more than once, during separate respiratory cycles. The results may then be averaged to provide EEG data for each particular scent.

[0082] The special subspace is extracted – step 720 – for the training data 716. The temporal subspace is also extracted – step 722 – for the training data 716. These subspaces are used to identify characteristics of the subject's olfactory response to particular scents.

Particular characteristics with a strong correlation to a particular scent are then extracted to optimise a subspace formed from the spatial and temporal subspaces – step 724. The subspace characteristics can form a feature space for classification through learning algorithms, for example, SVM(Support Vector Machines), LDA(Linear Discriminative Analysis) or ANN (Artificial Neural Network) etc. – step 726. The modelling process using training data generates a subjective preference model – step 728. Thus the subjective preference model 728 is a computation model of user preference – i.e. a classifier. The classifier receives its input in the form of one or more segments or time periods of raw EEG data. In this instance, the raw EEG data may be phase-locked to the timing of respiratory events. The raw EEG data is then transformed into a value that quantifies the preference (e.g. like, dislike or neutrality towards a particular scent) of the user. Thus the classifier involves EEG feature extraction and a linear or nonlinear discriminative transformation mechanism such as the SVM and ANN mentioned above. With new data, e.g., the subject's test data 703, the model can be applied for preference identification – step 730.

[0083] Characteristics of EEG data (e.g. temporal and/or spatial features) derived during periods (e.g. of inspiration) when the subject is exposed to another scent per, for example, step 202 of method 200, may then be compared to the model to determine if those characteristics are exhibited in the preference model. This enables the subject's olfactory response to the said scent to be categorised as a positive, negative or neutral response based on a similar response having been experienced during testing with the test set of scents.

[0084] Figure 8 is a block diagram showing an exemplary computer device 800, which may correspond to computer system 100, in which embodiments of the invention may be practiced. The computer device 800 may be a mobile computer device such as a smart phone, a wearable device, a palm-top computer, and multimedia Internet enabled cellular telephones, and connected or integral scent delivery device and respiratory sensor.

[0085] As shown, the computer device 800 includes the following components in electronic communication via a bus 806:

(a) a display 802;

(b) non-volatile (non-transitory) memory 804;

(c) random access memory ("RAM") 808;

(d) N processing components 810;

(e) a transceiver component 812 that includes N transceivers; and

(f) user controls 814 – in some embodiments the controls are performed through display 802.

[0086] The transceiver 812 may be connected to one or more appliances 818 – such as the respiratory sensor 104, scent delivery device 102 and EEG sensor array 106. The one or more processors 108 of computing device 100 may be performed by the N processing components 810 of mobile computer device 800, for example.

[0087] Although the components depicted in Figure 8 represent physical components, Figure 8 is not intended to be a hardware diagram. Thus, many of the components depicted in Figure 8 may be realized by common constructs or distributed among additional physical components. Moreover, it is certainly contemplated that other existing and yet-to-be developed physical components and architectures may be utilized to implement the functional components described with reference to Figure 1.

[0088] The display 802 generally operates to provide a presentation of content to a user, and may be realized by any of a variety of displays (e.g., CRT, LCD, HDMI, micro-projector and OLED displays). The display 802 may be a touch screen display through which an operator may control the process of scent preparation, delivery and data acquisition.

[0089] In general, the non-volatile data storage 804 (also referred to as non-volatile memory) functions to store (e.g., persistently store) data and executable code, and may be none, any or all of media and databases 804, 806 and 812 of computer system 800.

[0090] In some embodiments for example, the non-volatile memory 804 includes bootloader code, modem software, operating system code, file system code, and code to facilitate the implementation components, well known to those of ordinary skill in the art, which are not depicted nor described for simplicity.

[0091] In many implementations, the non-volatile memory 804 is realized by flash memory (e.g., NAND or ONENAND memory), but it is certainly contemplated that other memory types may be utilized as well. Although it may be possible to execute the code from the non-volatile memory 804, the executable code in the non-volatile memory 804 is typically loaded into RAM 808 and executed by one or more of the N processing components 810.

[0092] The N processing components 810 in connection with RAM 808 generally operate to execute the instructions stored in non-volatile memory 804. As one of ordinarily skill in the art will appreciate, the N processing components 810 may include a video processor, modem processor, DSP, graphics processing unit (GPU), and other processing components.

[0093] The transceiver component 812 includes N transceiver chains, which may be used for communicating with external devices via wireless networks. Each of the N transceiver chains may represent a transceiver associated with a particular communication scheme. For example, each transceiver may correspond to protocols that are specific to local area networks, cellular networks (e.g., a CDMA network, a GPRS network, a UMTS networks), and other types of communication networks.

[0094] The system 800 of Figure 8 may be connected to any appliance 818, such as a respiratory sensor 104, scent delivery device 102, an EEG sensor array 106, or an external database 812 from which model EEG data and stimulated EEG data (e.g. EEG data recorded during periods of inspiration during which the subject was responding to a delivered scent) may be acquired.

[0095] It should be recognized that Figure 8 is merely exemplary and in one or more exemplary embodiments, the functions described herein may be implemented in hardware, software, firmware, or any combination thereof. If implemented in software, the functions may be stored on or transmitted over as one or more instructions or code encoded on a non-transitory computer-readable medium 804. Non-transitory computer-readable medium 804 includes both computer storage medium and communication medium including any medium that facilitates transfer of a computer program from one place to another. A storage medium may be any available medium that can be accessed by a computer.

[0096] Throughout this specification, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.

[0097] The reference to any prior art in this specification is not, and should not be taken as, an acknowledgment or any form of suggestion that the prior art forms part of the common general knowledge.

CLAIMS

1. A system for sensing an olfactory response of a subject to one or more scents, comprising:

- a scent delivery device for delivering the one or more scents to the subject;
- a respiration sensor device for detecting one or more respiratory events of the subject;
- an electroencephalogram (EEG) sensor array for sensing brain activity of the subject and producing therefrom an EEG signal exhibiting the olfactory response of the subject to the one or more scents; and
- at least one processor,

wherein the at least one processor is configured to:

compute the one or more respiratory events to determine one or more periods during which the subject may be responding to the one or more scents;

derive, from the EEG signal, EEG data corresponding to the one or more respiration cycles of a predetermined time period; and

determine the olfactory response of the subject to the one or more scents by comparing the EEG data to model EEG data representing a predetermined olfactory condition of the subject.

2. A system according to claim 1, wherein the at least one processor is configured to time delivery of the one or more scents, by the scent delivery device, based on the one or more respiratory events.

3. A system according to claim 2, wherein the one or more respiratory events comprise one or both of an onset of inspiration and an onset of expiration.

4. A system according to claim 3, wherein the at least one processor is configured to synchronise delivery of the one or more scents, by the scent delivery device, with or based on:

the onset of inspiration; or

the onset of expiration.

5. A system according to claim 4, wherein the at least one processor is configured to cause the scent delivery device to commence delivering the one or more scents to the subject over a full respiration cycle, commencing on the onset of expiration.

6. A system according to claim 1, wherein the scent delivery device is configured to deliver a single scent, of the one or more scents, over any particular respiratory cycle.

7. A system according to claim 1, wherein the one or more scents comprise a plurality of scents and the scent delivery device is configured to deliver the scents in either:

random order; or

based on a similarity between successively delivered scents.

8. A system according to claim 1, wherein the EEG signal further exhibits an olfactory condition of the subject when not exposed to any scent of the one or more scents, and wherein the at least one processor is configured to compute the model EEG data from the EEG signal and the respiratory events, the model EEG data derived from brain activity of the subject over one or more inspiration periods during which the subject was not exposed to any scent of the one or more scents.

9. A system according to claim 8, wherein the respiration sensor is configured to compute a short-term respiratory consistency index (ST-RCI) for specifying a respiratory condition of the subject.

10. A system according to claim 9, wherein the at least one processor is configured to accept or reject the EEG data based on the respiratory condition of the subject and specified by the ST-RCI.

11. A system according to claim 9, wherein the ST-RCI is computed according to the formula:

$$\epsilon = \frac{c_1}{N}\sum_{j=1}^{N}(t_j - \bar{t})^2 + \frac{c_2}{N}\sum_{j=1}^{N}(a_j - \bar{a})^2$$

where N is a number of detected respiratory cycles in a pre-defined time window, t_j and a_j are time and amplitude of detected inhale/exhale points (i.e. peaks and troughs) for a j^{th} respiratory cycle, $\bar{t}$ and $\bar{a}$ are mean time and amplitude over all N detected respiratory cycles, and c_1 and c_2 are coefficients for associating variances in time and amplitude.

12. A system according to claim 1, wherein the respiration sensor detects the respiratory events in real-time.

13. A system according to claim 1, wherein the EEG data comprises one or more portions of the EEG signal and, where the EEG data comprises two or more portions of the EEG signal those two or more portions are separated by a refractory period.

14. A system according to claim 1, wherein the model EEG data comprises one or more characteristics indicating a particular olfactory response is positive or negative, and determining the olfactory response of the subject comprises determining which of the one or more characteristics is exhibited in the EEG data acquired over the one or more inspiration periods of the subject during which the one or more scents were delivered to the subject and thereby determining whether the EEG data is indicative of a positive olfactory response.

15. A method for sensing an olfactory response of a subject to one or more scents, comprising:

- delivering, by a scent delivery device, the one or more scents to the subject;
- detecting, by a respiration sensor device, one or more respiratory events of the subject;
- sensing brain activity of the subject using an electroencephalogram (EEG) sensor array and producing therefrom an EEG signal exhibiting the olfactory response of the subject to the one or more scents;

- computing the one or more respiratory events to determine one or more periods during which the subject may be responding to the one or more scents;
- deriving, from the EEG signal, EEG data corresponding to the one or more periods;
- comparing the EEG data to model EEG data representing a predetermined olfactory condition of the subject; and
- determining the olfactory response of the subject to the one or more scents.

16. A method according to claim 15, further comprising timing delivery of the one or more scents, by the scent delivery device, based on the one or more respiratory events.

17. A method according to claim 16, wherein timing delivery comprises synchronising delivery of the one or more scents with, or based on, one of the onset of inspiration and the onset of expiration.

18. A method according to claim 17, wherein delivering the one or more scents to the subject comprises delivering each scent of the one or more scents over a respective full respiration cycle, commencing on the onset of expiration.

19. A method according to claim 18, wherein the one or more scents comprise a plurality of scents and delivering the one or more scents to the subject comprises delivering the scents in one of a random order and an order based on a similarity between successively delivered scents.

20. A method according to claim 15, wherein the EEG signal further exhibits an olfactory condition of the subject when not exposed to any scent of the one or more scents, the method further comprising computing the model EEG data from the EEG signal and the respiratory events, the model EEG data derived from brain activity of the subject over one or more inspiration periods during which the subject was not exposed to any scent of the one or more scents.

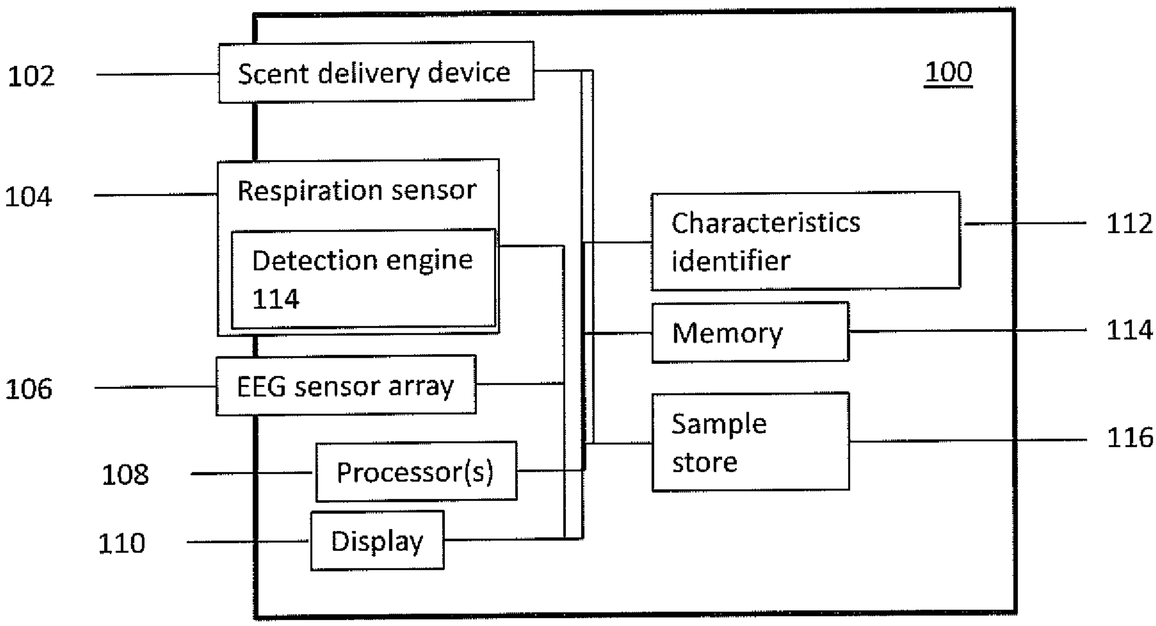


Figure 1

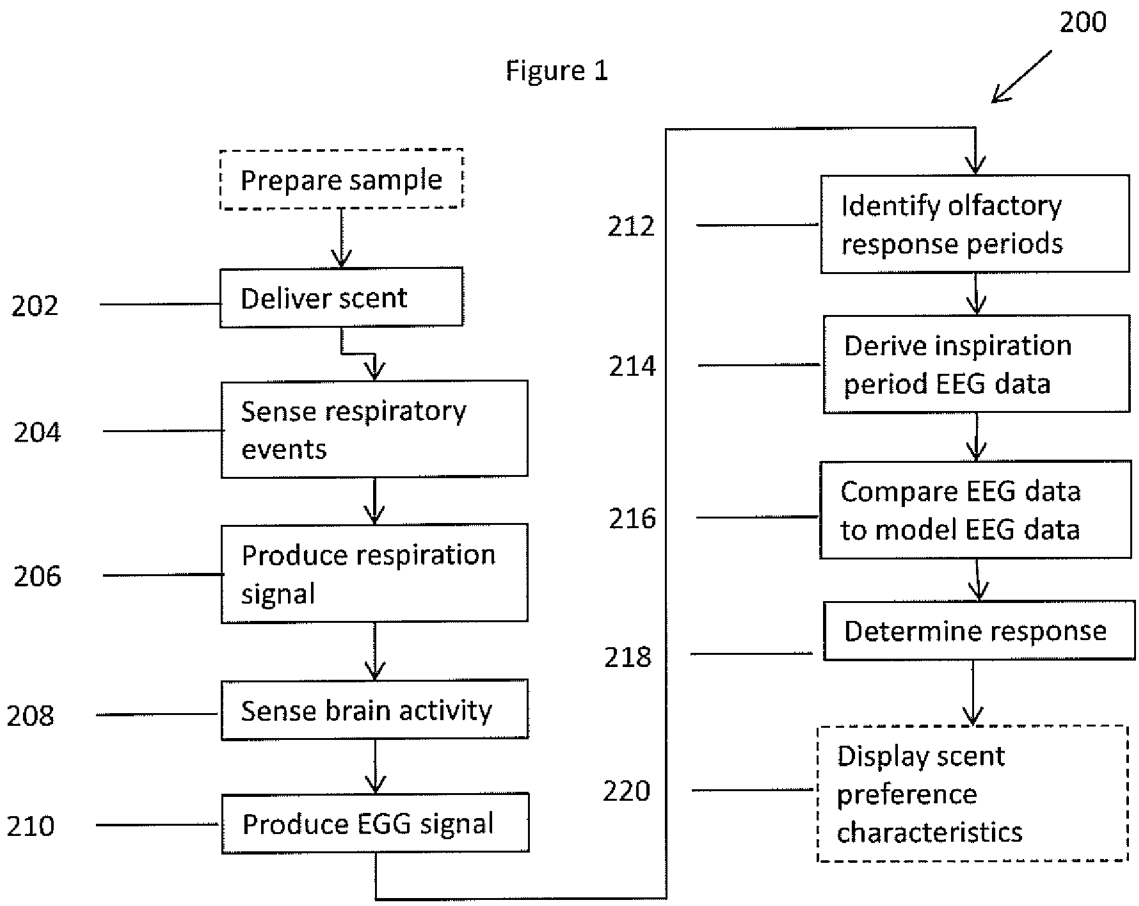


Figure 2

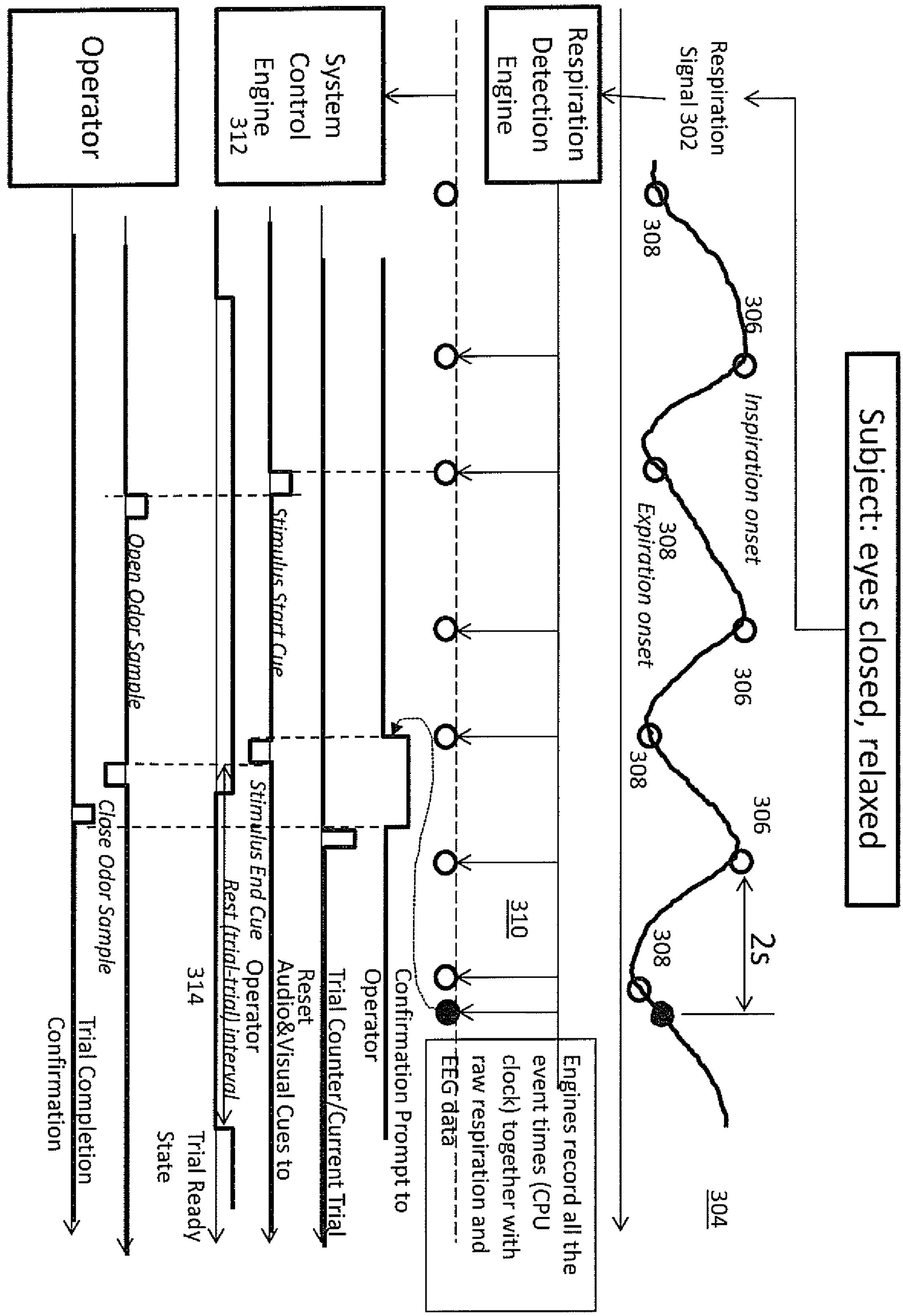

Subject: eyes closed, relaxed
Respiration Signal 302
304
306
308
Inspiration onset
Expiration onset
2s
Respiration Detection Engine
310
Engines record all the event times (CPU clock) together with raw respiration and EEG data
System Control Engine 312
Operator
Confirmation Prompt to Operator
Trial Counter/Current Trial Reset
Audio&Visual Cues to Operator
Stimulus Start Cue
Stimulus End Cue
Rest (trial-trial) interval
314
Trial Ready State
Open Odor Sample
Close Odor Sample
Trial Completion Confirmation

Figure 3

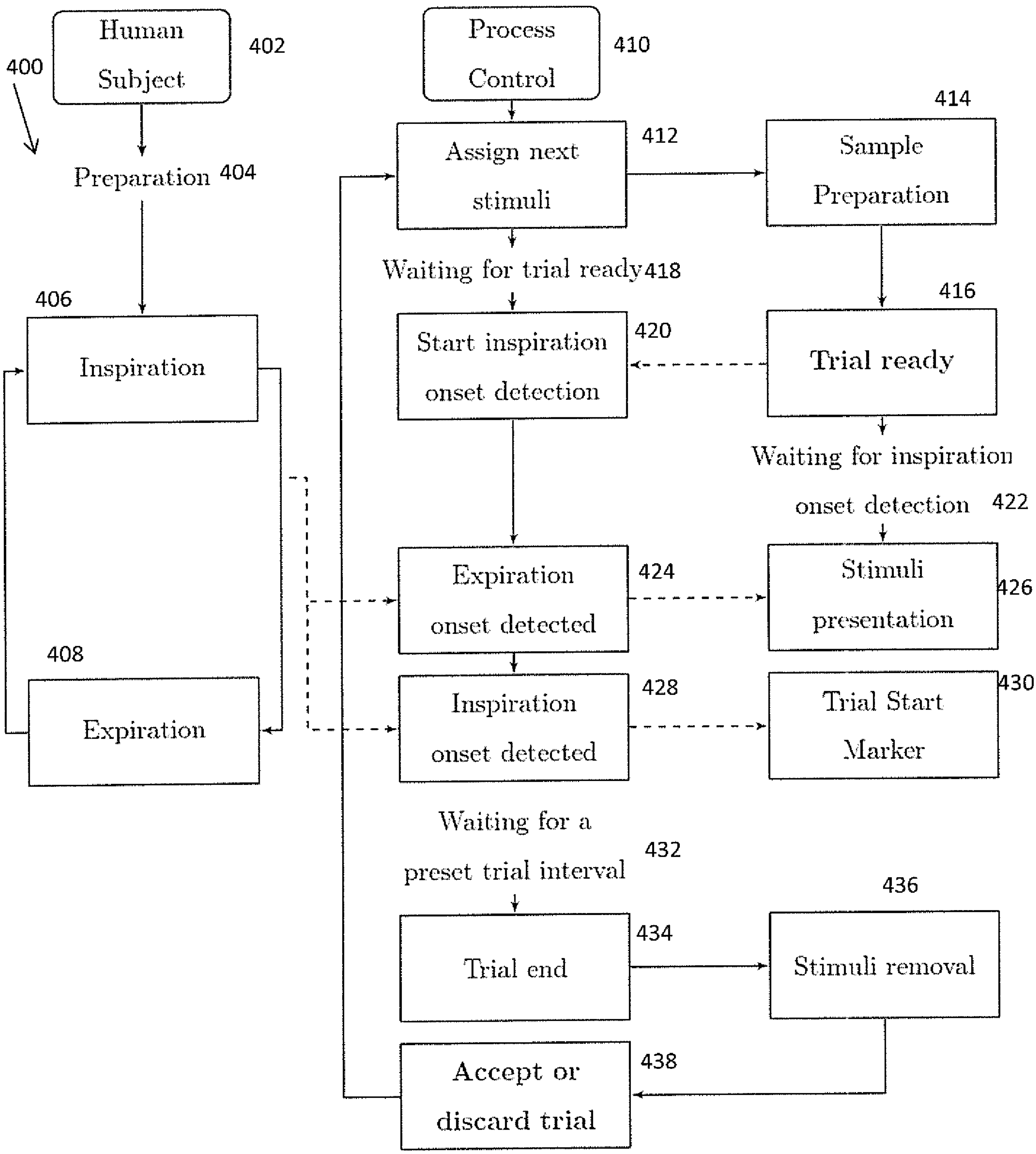

400
Human Subject
402
Preparation
404
406
Inspiration
408
Expiration
Process Control
410
Assign next stimuli
412
Waiting for trial ready
418
Start inspiration onset detection
420
Expiration onset detected
424
Inspiration onset detected
428
Waiting for a preset trial interval
432
Trial end
434
Accept or discard trial
438
Sample Preparation
414
Trial ready
416
Waiting for inspiration onset detection
422
Stimuli presentation
426
Trial Start Marker
430
Stimuli removal
436

Figure 4

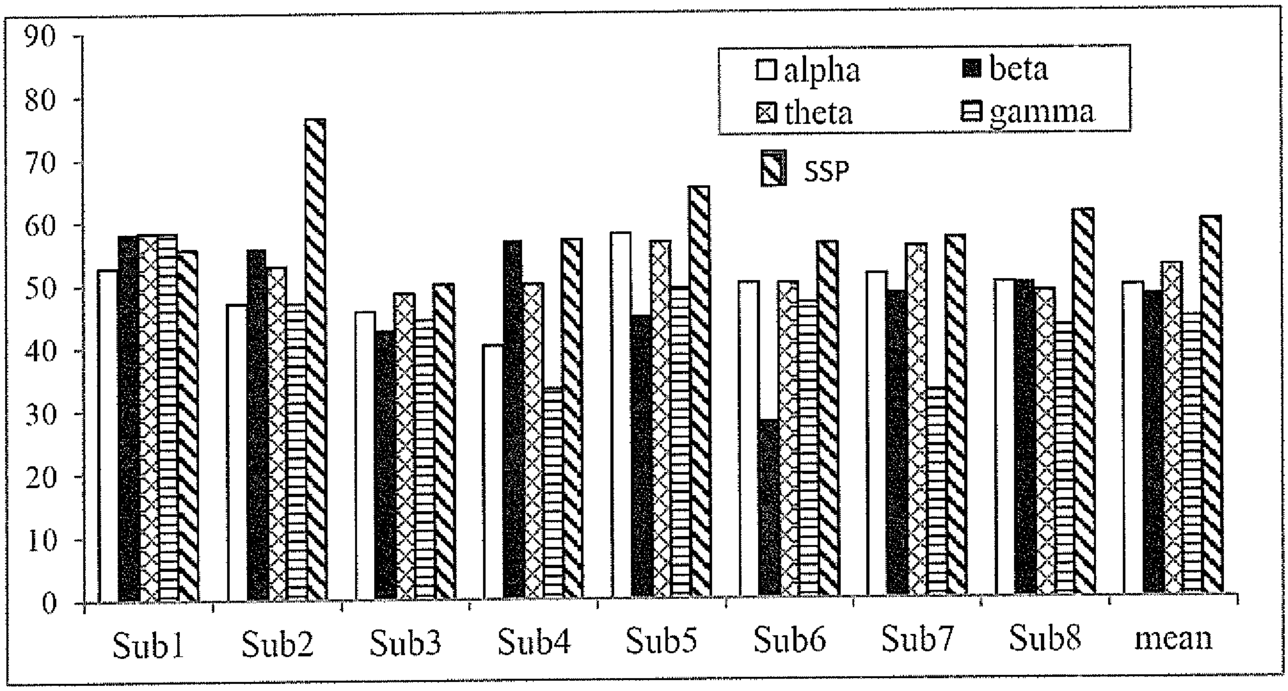

90
80
70
60
50
40
30
20
10
0
alpha
beta
theta
gamma
SSP
Sub1
Sub2
Sub3
Sub4
Sub5
Sub6
Sub7
Sub8
mean

Figure 5

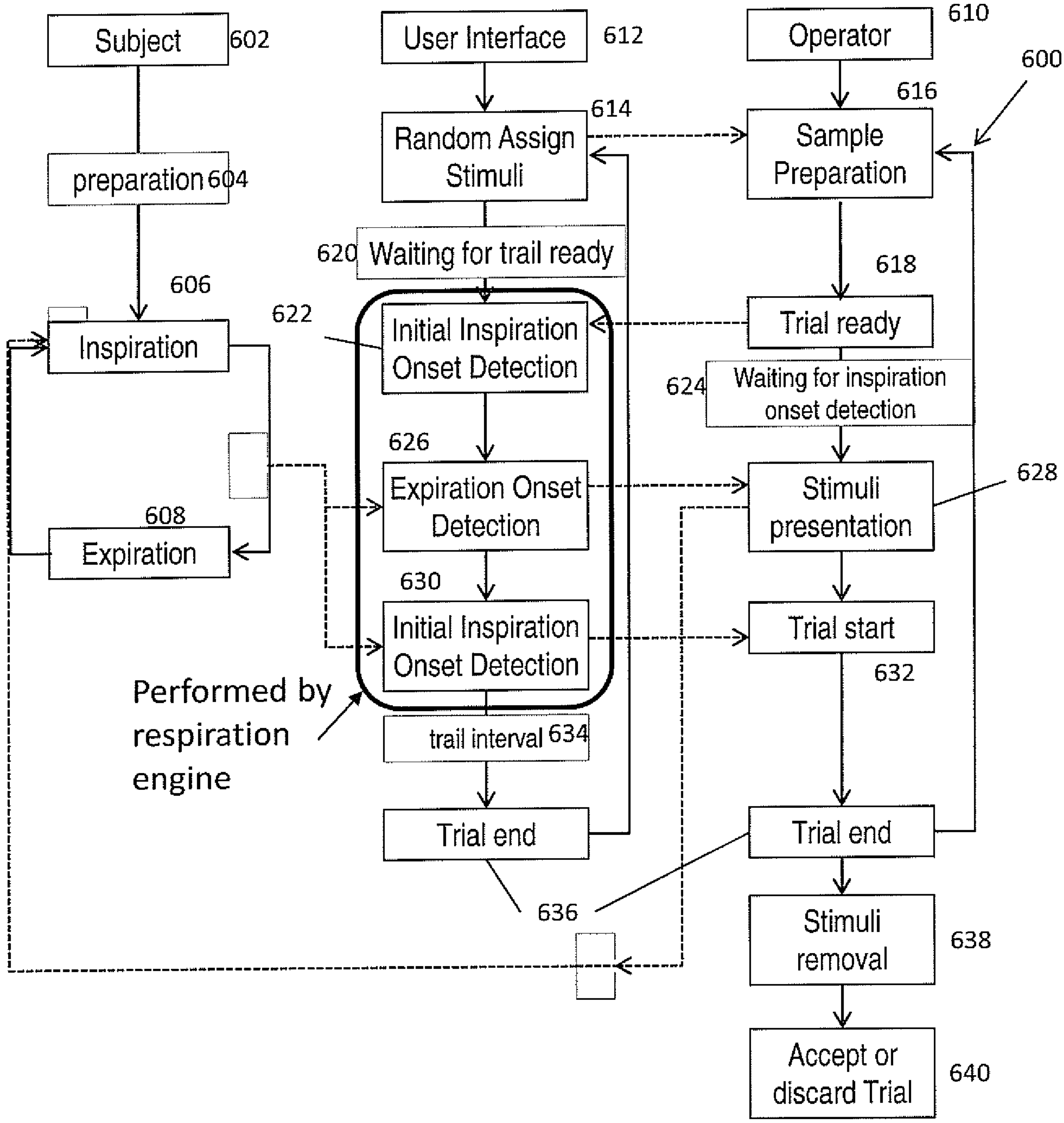
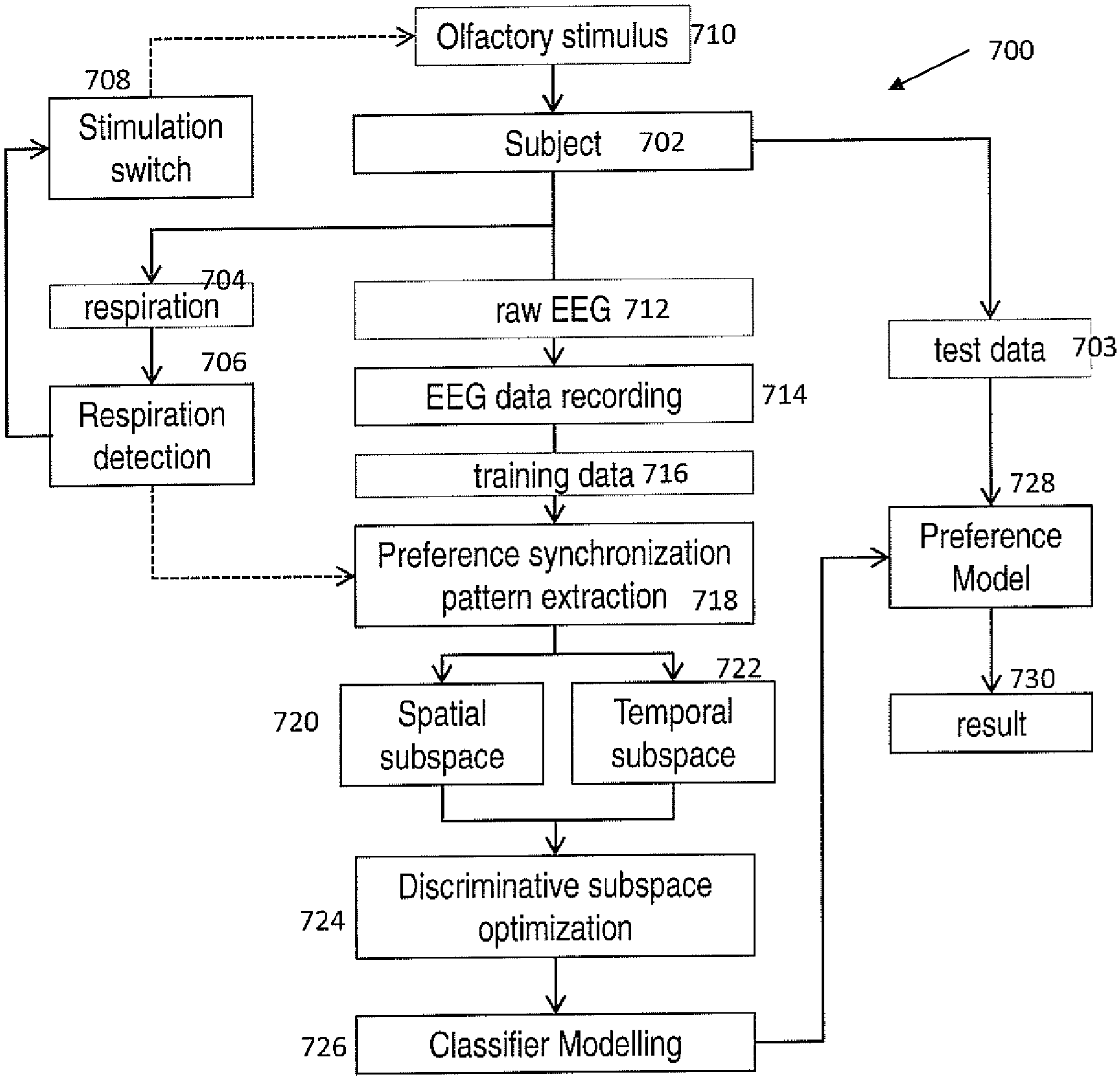

Subject
602
preparation
604
606
Inspiration
608
Expiration
User Interface
612
Random Assign Stimuli
614
620
Waiting for trail ready
622
Initial Inspiration Onset Detection
626
Expiration Onset Detection
630
Initial Inspiration Onset Detection
Performed by respiration engine
trail interval
634
Trial end
636
Operator
610
600
616
Sample Preparation
618
Trial ready
624
Waiting for inspiration onset detection
Stimuli presentation
628
Trial start
632
Trial end
Stimuli removal
638
Accept or discard Trial
640

Figure 6



Olfactory stimulus 710
700
708
Stimulation switch
Subject 702
704
respiration
raw EEG 712
706
test data 703
Respiration detection
EEG data recording
714
training data 716
728
Preference Model
Preference synchronization pattern extraction 718
722
730
720
Spatial subspace
Temporal subspace
result
Discriminative subspace optimization
724
726
Classifier Modelling

Figure 7

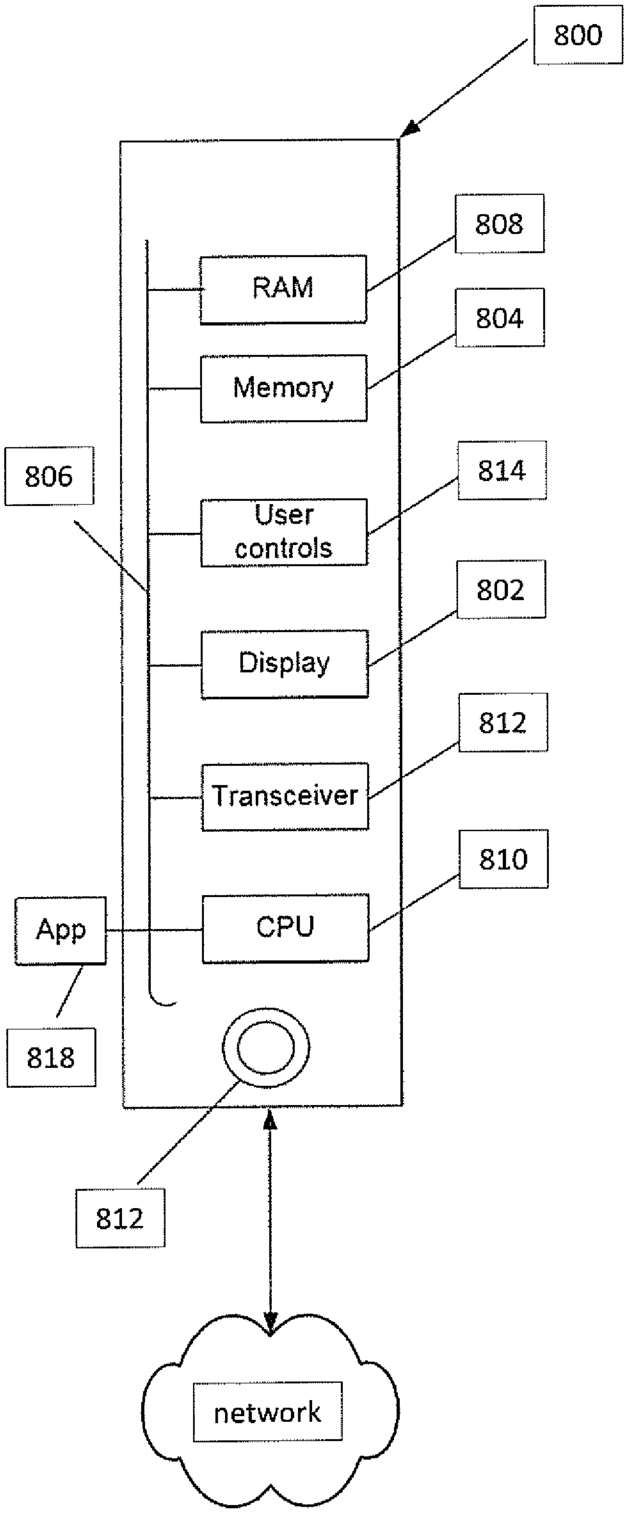

800
808
RAM
804
Memory
806
814
User controls
802
Display
812
Transceiver
810
App
CPU
818
812
network

Figure 8

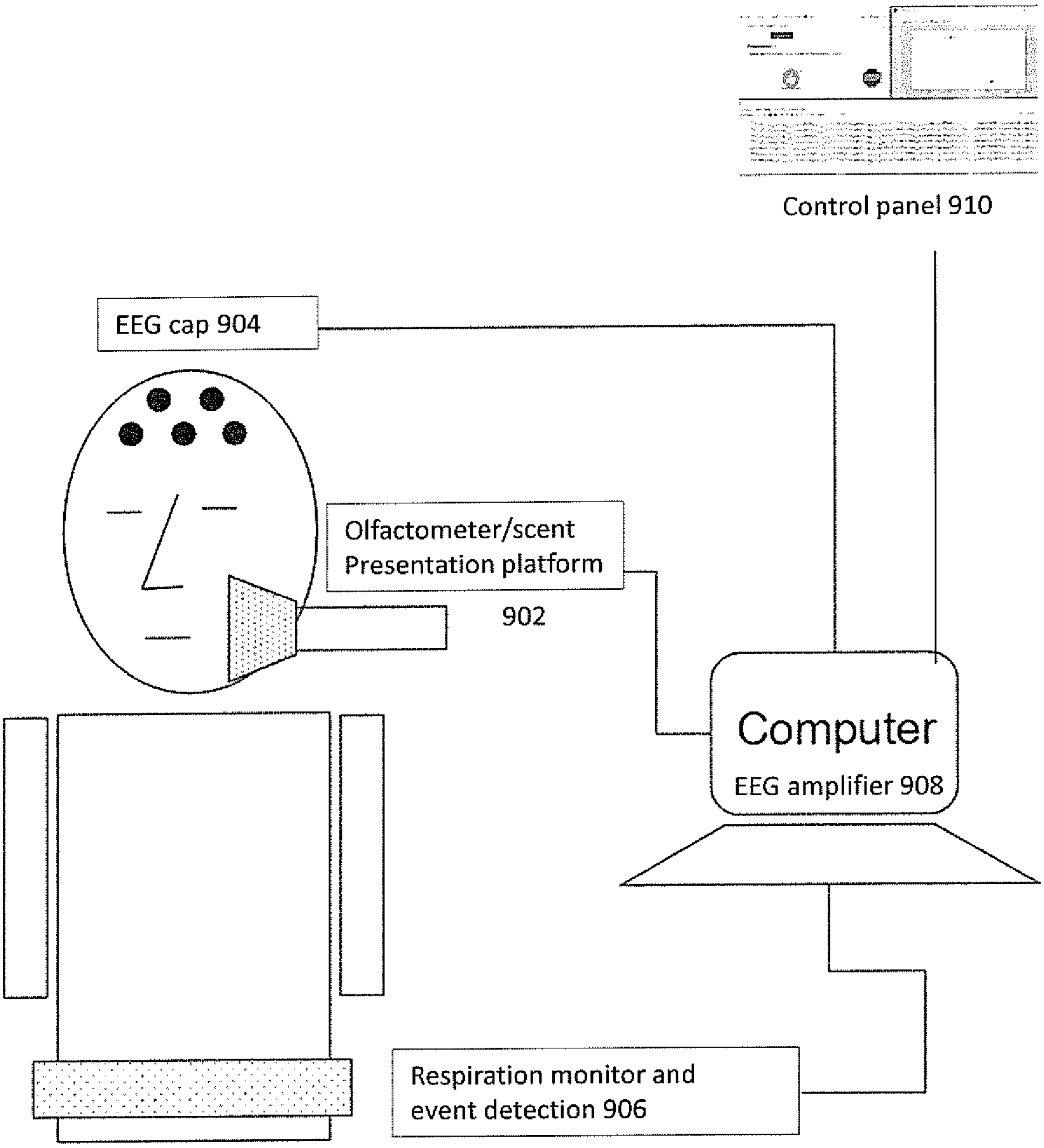

Control panel 910
EEG cap 904
Olfactometer/scent
Presentation platform
902
Computer
EEG amplifier 908
Respiration monitor and
event detection 906

Figure 9

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SG2018/050302

A. CLASSIFICATION OF SUBJECT MATTER

A61B 5/0484 (2006.01)   A61B 5/113 (2006.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

FAMPAT, INCOPAT and IEEE: compute, respiratory, compare, EEG, olfactory, scent, 检测, 呼吸, 比较, 脑电图, 嗅觉, 气味 and related terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	ZHANG Z. ET AL., Toward EEG-based Olfactory Sensing through Spatial Temporal Subspace Optimization. *2017 International Conference on Orange Technologies* , 10 December 2017, pages 168 - 171 [Retrieved on 2018-07-31] <DOI: 10.1109/ICOT.2017.8336114> section I, 4th paragraph; section II, A, B; section III, A, B	1-9, 12-20
A	JP 2018-033580 A (DIMENSIONIA Â· FRONT) 8 March 2018 whole document of the machine translation	-
A	US 2008/0255949 A1 (GENCO S. J. ET AL.) 16 October 2008 whole document	-
A	US 2005/0022034 A1 (CHAUDHARI U. V. ET AL.) 27 January 2005 whole document	-
A	CN 104460948 A (NANJING DAWU EDUCATION & TECHNOLOGY) 25 March 2015 whole document of the original non-English language document (a machine translation is enclosed **only** for your reference)	-

☐ Further documents are listed in the continuation of Box C.   ☒ See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
17/08/2018 *(day/month/year)*	*14/09/2018* *(day/month/year)*

Name and mailing address of the ISA/SG	Authorized officer
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Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 2018-033580 A	08/03/2018	NONE	
US 2008/0255949 A1	16/10/2008	NONE	
US 2005/0022034 A1	27/01/2005	NONE	
CN 104460948 A	25/03/2015	NONE	