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Research report

Validation of laughter for diagnosis and evaluation of depression

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ABSTRACT

Background: In the medical field, laughter has been studied for its beneficial effects on health and as a therapeutic method to prevent and treat major medical diseases. However, very few works, if any, have explored the predictive potential of laughter and its potential use as a diagnostic tool.
Method: We registered laughs of depressed patients ($n=30$) and healthy controls ($n=20$), in total 934 laughs (517 from patients and 417 from controls). All patients were tested by the Hamilton Depression Rating Scale (HDRS). The processing was made in Matlab, with calculation of 8 variables per laugh plosive. General and discriminant analysis distinguished patients, controls, gender, and the association between laughter and HDRS test.
Results: Depressed patients and healthy controls differed significantly on the type of laughter, with 88% efficacy. According to the Hamilton scale, 85.47% of the samples were correctly classified in males, and 66.17% in women, suggesting a tight relationship between laughter and the depressed condition.
Limitations: (i) The compilation of humorous videos created to evoke laughter implied quite variable chances of laughter production. (ii) Some laughing subjects might not feel comfortable when recording. (iii) Evaluation of laughter episodes depended on personal inspection of the records. (iv) Sample size was relatively small and may not be representative of the general population afflicted by depression.
Conclusions: Laughter may be applied as a diagnostic tool in the onset and evolution of depression and, potentially, of neuropsychiatric pathologies. The sound structures of laughter reveal the underlying emotional and mood states in interpersonal relationships.

1. Introduction

Laughter has been virtually absent from the international research scene until last two decades (Provine, 2000). Notwithstanding the important research progress and the new insights gained, fundamental aspects of the phenomenon are not clarified yet. More than in the biomedical field itself or in pathological laughter, it is spontaneous laughter – or technically, *Duchenne* laughter – which continues to present the greatest unsolved questions: in terms of stimuli, production causes, circuit detection, acoustic structures, neurocognitive correlates, relationships with emotions, social context, etc. In this paper we are going to explore whether laughter production may correlate or not with an important neuropsychiatric pathology, depression, and how the results of this correlation may have a potential application to clinical diagnostic.

Laughter is an innate reaction of human behaviour, of Anthropoid provenance, which is elicited by the concurrence of certain external stimuli and some internal reactions, mostly related to social interactions (Provine, 2000; Bachorowski and Owren, 2002). Both the external interaction and the inner background of the individual conspire together for the occurrence of laughter, which apparently is a kind of social signal of individual wellness in front of apparently inconsistent or problematic situations (Marijuán and Navarro, 2011; Hurley et al., 2011). However, some physical and chemical stimuli may also directly elicit the spontaneous behaviour of laughter (Provine, 2000).

Currently there are three main theories explaining the causes of laughter and the conjunction of external and internal phenomena that elicit it (Rozengurt, 2011). *Theories of relief* come from Freud (1928) suggesting that laughter can release tension and "psychic energy" that are built up for inhibiting taboo feelings such as sex or

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death. *Superiority theories* argue that laughter expresses the subject's superiority over other people in the social interaction (Martin, 2006; Portmann, 2000). And *incongruity theories* conceive laughter as a result of simultaneous occurrence of incompatible elements in the current interactions (Martin, 2006; Suls, 1972; Attardo, 1994). The latter approach has also been formulated within a "computational turn", presenting laughter as an information-processing tool in charge of debugging the inconsistencies of cortical databases (Hurley et al., 2011). A further "neurocomputational hypothesis" has been proposed by some of the present authors (Mariiuán and Navarro, 2011), where laughter is considered as a behavioural outcome caused by sudden neurodynamic information gradients, actually arising in a variety of physical, behavioural, and social problem-solving circumstances, which become positively finalized—and are thus spontaneously expressed as a signal of the subject's wellness and social competence.

Indeed the above plurality of theories accommodates well with the complexity of the phenomenon and the basic unsolved questions that remain; it also denotes the multifarious stimuli and variegated inner and social circumstances that may produce laughter along the daily life of the individual. Laughter closely accompanies human relationships: of babies and toddlers with their parents, children play, adolescent groups, courtship, parenthood, group coalitions, social small-talk, friendship, etc. Quite possibly, laughter as a pervasive phenomenon in human societies is centred on the formation and maintenance of the neural engrams subtending "social bonds" (Marijuán and Navarro, 2011). It is understandable that in mental pathologies that seriously affect the relational capabilities of individuals, laughter also becomes severely affected both in its production circumstances and in its acoustic expressive contents—as we are going to study here.

Medically, the study of pathological laughter (Poeck, 1985) has pioneered the field respect other behavioural and cognitive approaches to spontaneous laughter. Lesion studies for instance (i.e. damage to frontal cortex areas), have pinpointed the participation of many specific areas in humour perception and laughter production, and have also dispelled too simple neurological and cognitive assumptions. Unlike in emotional responses relatively confined to specific cerebral localizations, it has been authenticated that laughter is associated with activation of numerous areas: left, front, right, and rear of the cortex, as well as motor areas, cerebellum, limbic system, subcortical nuclei, hypothalamus, etc. According to Wild et al. (2003) the neuro-anatomical command system for laughter production includes two pathways: the voluntary, involving the premotor opercular areas, the motor cortex, and pyramidal tract; and the involuntary, involving amygdala, thalamic, hypothalamic and subthalamic nuclei. Both pathways are controlled by a single centre located in the dorsal upper pons. Further, in the overall occurrence of laughter three main neural systems would be involved: a cognitive area, mainly frontal cortex, which comprehends the high level processing of stimuli; the motor area that generates a series of muscle movements producing sounds and facial expressions, identified as the supplemental motor cortex; and the emotional area that provides joy and happiness feelings, mainly the nucleus accumbens (Ariniello, 2001; Hasan and Hasan, 2009; Parvizi et al., 2001). See the flow chart in Fig. 1.

Laughter has also been studied for its effects on health and as a therapeutic method to prevent, detect, and treat major medical diseases (Penson et al., 2005). For instance, it is well authenticated that major depression affects humour appreciation in patients with symptoms such as feelings of anhedonia, hopelessness, guilt thoughts or inability to concentrate; schizophrenia patients exhibit a humour deficit too—as already pointed by Corcoarns et al. (1997). An important population study of the relationship between laughter production and the occurrence of certain autoimmune and mental health diseases has been conducted by Hasan and Hasan (2009), additionally suggesting that laughter history of patents should be incorporated into the general practice of medical history taking. A major clinical review has been performed by Gelkopf (2011), highlighting the therapeutic potential of laughter and humour in a variety of clinical settings and treatments: pain relief, immune function, stress, interpersonal processes, psychotherapy frameworks, etc. Overall, there is clinical evidence that "serious mental illnesses" may benefit from the use of humour and laughter, facilitating medication adherence, therapeutic alliance, psychotherapy work and patient empowerment.

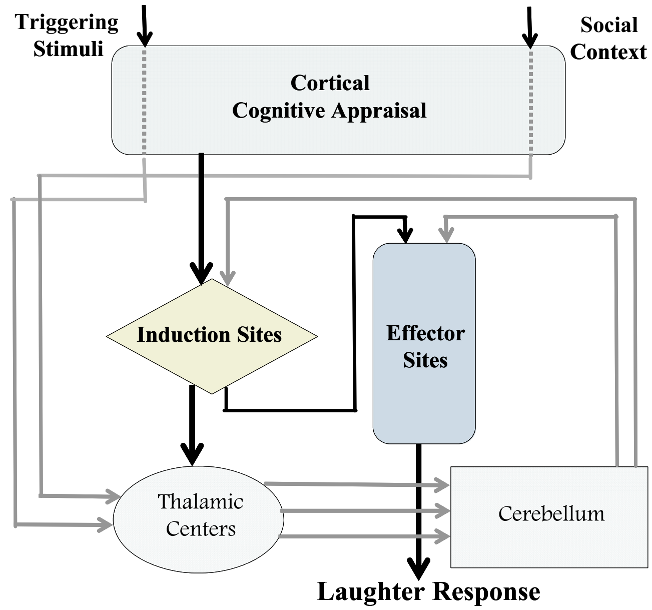

Fig. 1. Main neural systems and pathways involved in laugther. The initial stage is the cognitive appraisal (cognitive system), which mainly corresponds to the frontal cortex, together with the sensory and multimodal areas related to the kind of triggering stimuli (visual, auditory, tactile, linguistic). At this stage, the intensity, emotional content, and duration of laughter are not well gauged yet, as they should be in accord not only with the triggering stimuli, but also with the social context and with the reaction produced in the whole memory contents of the subject. Further, the emotionally-laden induction sites (emotional system) comprehend the amygdala, ventral striatum, and anterior cingulated cortex. The motor or effector sites (motor system) include motor cortices, hypothalamus, and cranial nerve nuclei. The three previous systems (cognitive, emotional, motor) relay to the telencephalic structures, and from there to the cerebellum, which computes the different influences that shape the final laughter response conveyed through the motor system. See Parvizi et al. (2001) for a careful discussion of all these pathways and systems.

A number of research findings and contributions to recent literature suggest that laughter reflects the whole mental and physical condition of individuals (Gelkopf, 2011; Bennett and Lengacher, 2008; Adams, 2008; Walter et al., 2007). In the extent to which that assumption holds, a better understanding of the *sound structures* of laughter, in their close relationship with the emotional and mood states of the subjects, could imply a potential use of laughter as an indicator of well-being and mental health, helping to distinguish the presence of neuropsychiatric pathologies. Very few works have been addressed in that direction, trying to explore the predictive potential of laughter (Uekermann et al., 2008). Specifically, detecting the differences of laughter between healthy subjects and depressed patients will be addressed in the present study.

Therefore, this study investigates whether one of the most important neuropsychiatric conditions, depression, can be detected using laughter as a screening test. In the extent to which this attempt is successful, its results would provide new neuroscientific elements for laughter analysis, as well as new biomedical tools for diagnostic and evaluation in mental health.

2. Material and methods

2.1. Subjects

We registered laughs of 50 individuals, 30 patients and 20 healthy people, comprising men and women between the age of 20 and 65; their laughs were registered individually by means of a digital voice recorder. The period of recruitment was from March to July 2012. More patients than controls were recruited in order to make possible a classification of depression rating and to correlate it with laughter registers. All the individuals were Spanish and none suffered any mental illness that prevented the realization of the task, so they were able to understand the entire humour sketches and complete the questionnaires. Inclusion criteria for entry were as follows: (i) age 18–65 years, (ii) diagnosis of depression according to the MINI psychiatric interview administered by a psychiatrist (Sheehan et al., 1998), (iii) good mastery of Spanish language, (iv) No severe psychiatric disorders (psychosis, bipolar disorder, obsessive compulsive disorder, eating behaviour disorders) according to MINI, (v) no clinical o psychological illness that prevented the realization of the test. The patients were recruited in psychiatry outpatients of Miguel Servet Hospital, Zaragoza, Spain. Besides, a group of subjects was selected who did not suffer depression and accomplished all inclusion criteria except ii. The protocol was approved by the Regional Ethics Committee of Aragon.

2.2. Psychological test

To measure the severity of clinical depression symptoms, all patients were tested by the Hamilton Depression Rating Scale (HDRS). The HDRS test is probably the most widely used instrument to measure severity of depression both in clinical practice and in research on mood disorders. In the present study the original 21-item version was administered in its Spanish validated version (Ramos-Brieva and Cordero-Villafafila, 1988).

2.3. Compilation of laughter

The compilation of laugh videos, most of them uploaded in YouTube by the video protagonists themselves, was made throughout Internet search. These videos provide humorous circumstances to evoke laughter in most types of people. They include funny sketches, falls, jokes, famous movie characters, well-known humorists, etc. A specific protocol was generated, orderly including the numerous kinds of visual and acoustic stimuli used to generate laughter during two sessions of 20 min each. The records were captured with a digital voice recorder, Olympus VN-712PC.

Spontaneous laughter from each participant was recorded in a wav archive encoded in 16-bit PCM format, sampled at 22,050 Hz. We separated every laugh episode by both hearing the recordings and visualizing the waveforms, using the sound analysis program Adobe Audition. Through this software we distinguished each laughter episode, so that entire laughter utterances were selected and stored separately. The evaluation of whether a laughter episode was suitable or not depended on our decision. The validity of the audio segment was conditioned mainly by its clarity; overlapped speech-laugh or laugh–laugh segments were dismissed. All the laugh archives had well defined boundaries; they were recorded from only one individual and did not have any interfering noise like humming or throat clearing, otherwise laughs were discarded. This whole evaluation task is difficult to achieve with automatic laughter detectors, including machine learning methods and support vector machines; manually it is a slow process, but reliable enough.

In the sound analysis and characterization of laughter, the wide range of acoustic shapes requires segmentation in time domain. In order to classify laughter by means of hierarchical decomposition, it is useful to extract information from rhythm, but the classifying features can be computed only on specific segments. According to the conventions in laughter sound studies, each laughter bout consists of a certain number of discrete elements, called plosives, characterized by energy peaks separated by silences, and repeated in series every 210 ms approx. (Trouvain, 2003; Dupont et al., 2009). At this temporal level, bouts can be seen as alternating maxima and minima in waveform amplitude envelope. Syllables with voiced-unvoiced concatenation cannot be considered as a valid decomposition, such as the stereotypical “hahaha”, because there are several types of unvoiced laughs with noisy and irregular sounds.

In total, we registered laughs of 50 individuals, depressed patients ($n=30$) and healthy controls ($n=20$), and we compiled 934 well-formed laughs following the selection criteria just described (517 from patients and 417 from controls). On average, 17 laughs for patients and 21 for controls.

2.4. Laughter processing

The plosive automatic detector was implemented in Matlab. For this purpose we created a program that reads every sound archive

Table 1
The features extracted in our study for every plosive.

Feature	Description
Time duration	Counted in ms, the temporal succession of plosive durations gives an overview of theinner structure of the laughter episode
Fundamental frequency mean	Defined as the inverse of the smallest period of the vocal fold signal in the interval being analysed (every 10 ms)
Standard deviation of the fundamental frequency	Computed over successive short time frames of the signal, in order to determine range and variability of an instantaneous measurement
First three formants	Formants are spectral peaks in the whole range of the speech wave that provide information about the acoustic resonances in the vocal tract for every plosive
Average power or energy per sample	Derived from the amplitude of sound, it directly affects our perception of fundamental frequency, what is called pitch. The pitch is an interpretation of the listener thatinfluences the subjective interpretation of sound energy
Shannon's entropy	Defined as the measure of the variable information contained in the patterns of a message, as opposed to the portion of the message that is determined
Jitter	A cycle-to-cycle measure of the variations of fundamental frequency, expressed as a percentage
Shimmer	Defined as the average absolute difference between the amplitudes of consecutive periods, expressed as a percentage. It is equivalent to jitter in signal amplitude, that is, rapid variations in loudness
Harmonic to Noise Ratio (HNR)	Described as the energy ratio of fundamental frequency harmonics to noise components. HNR appears to be a more sensitive index of vocal function than other features
Percentage of voiced/unvoiced signal	The time that vocal cords vibration spend over a plosive versus the interval between plosives

and computes the mean energy values of concatenated signal frames, with a frame length of 21 ms and a shift of 5 ms. Due to the wide frequency distribution of unvoiced laughs (snort, grunt, etc), a spectral-domain method isn't adequate. Thereafter, the program finds the lowest energy points using a valley detection algorithm. To confirm if these points are accurately plosive limits, there should be at least 10% of maximum energy between two valleys and duration of 100 ms to discard spurious vocalizations. The number of plosives in an episode varied significantly, for example, one bout can contain in between one and eight plosives. However, to perform straightforward comparisons between laughter types, it is better to build vectors of fixed length. The features extracted in our study for every plosive are shown in Table 1: A *formant* is a concentration of acoustic energy around a particular frequency in the speech wave.

The outcome of this characterization is a data matrix consisting of all plosives sorted by individual laugh archives in rows, initially with 12 columns (variables) per plosive. Obviously, we had to compress data, restricting plosives to five and discarding other proved weak features (all of them tested in a previous study) such as Jitter, Shimmer, HNR and Average Power. Thus a total of 8 columns (variables) per plosive were analyzed.

2.5. Statistical analyses

General and discriminant analyses were conducted in STATGRAPHICS Plus version 5.1. Discriminant analysis of laughter for differentiating patients and controls was conducted, obtaining discriminant functions, canonical correlation, Wilk's Lambda, Fisher's linear discriminant function coefficients for each group, and the classification table. A similar analysis was carried out distinguishing gender, male or female, in both patients and controls. In patients only, also distinguishing gender, the association between laughter and Hamilton scale was studied using a similar statistical analysis.

3. Results

The general discriminant analysis was performed regardless of gender, with data classified into two groups (patients versus healthy or control subjects). It shows that patients and controls differed significantly on the type of laughter (Fig. 2) as evidenced by a discriminant function statistically significant ($p < 0.001$) that accounts for 100% of the variance. A high value of the canonical correlation (0.73) indicates a strong relationship between the group membership and discriminant function values. This fact is also manifested in the eigenvalue (1.15) with a proportion of 46% of the total variance (Wilk's Lambda) not explained by differences between groups. In consequence, the discriminant function takes different values in the groups considered, concluding that the model successfully discriminates between patients and healthy controls.

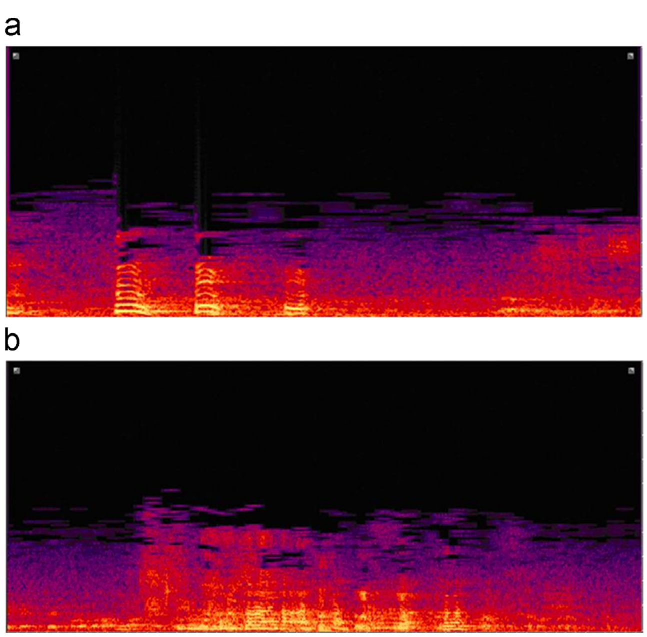

Fig. 2. Sonogram of laughter recorded from a (a) depressed patient and (b) healthy or normal control subject.

The classification table (Table 2) shows the results correctly predicted in the classification process, indicating an efficacy of 85.12%.

3.1. Depression diagnosis by means of laughter analysis and gender

The discriminants analysis conducted with only male gender, both patients and controls, indicates that the two groups differed significantly on the type of laughter, since the discriminant function is statistically significant ($p < 0.001$), accounting for 100% of the variance.

Likewise the discriminant analysis conducted with only female gender shows that patients and controls differed significantly on the type of laughter. The discriminant function is statistically significant ($p < 0.001$) and accounts for 100% of the variance. However, while in men the model explains 59.4% (Wilk's Lambda equal to 0.406) of the total variance explained by differences between groups, in women this percentage is somewhat lower and is equal to 57.7% (Wilk's Lambda equal to 0.423).

Table 3 displays the results correctly classified in male and female, indicating that 88.55% of the samples are correctly identified in males and 88.89% in females. This is a very important result of the present study.

3.2. Hamilton depression rating scale (HDRS) classification by laughter analysis

According to the HDRS scale, score intervals of 0–7 (normal), 8–13 (slight depression), 14–18 (moderately depression), 19–22 (severe depression) and greater than 23 (hard depression) were considered as 1–5 categories respectively. A discriminant analysis was performed without distinguishing between men and women, classifying the data in the five categories of the Hamilton scale.

Table 2
Classification table.

Groups	*Cases*	**(%)**
Patients	465 of 517	89.94
Controls	330 of 417	79.14

Overall: 85.12% cases correctly classified.

Table 3
Male and female classification table.

Groups	**Male**		**Female**	
	Cases	(%)	*Cases*	(%)
Patients	114 of 131	87.02	353 of 386	91.45
Controls	203 of 227	89.43	159 of 190	83.68
Overall: cases correctly classified	**88.55%**		**88.89%**	

Even when the first two discriminant functions are statistically significant ($p < 0.001$) representing both a cumulative percentage of 69.99% of the variance, the overall percentage of cases correctly classified was only 52.77% (efficacy). The statistical analysis was repeated separating subjects by gender, performing first a discriminant analysis with men suffering depression and then with depressed women.

The discriminant analysis conducted with only male shows two discriminant functions statistically significant ($p < 0.001$ and $p = 0.01$, respectively) accounting both for a cumulative percentage 90.52% of the variance (Fig. 3). In consequence, according to the five categories of the Hamilton scale, male patients significantly can be successfully classified by analyzing their laughter, with a efficacy of 85.47%. A high value of the canonical correlation in the first (0.83) and second (0.75) discriminant functions indicated a robust correlation between the group membership and discriminant function values. This fact is also manifested in the first (eigenvalue equal to 2.31) and second (eigenvalue equal to 1.32) discriminant functions. Likewise each discriminant function stands for a proportion of 9% and 31% of the total variance (Wilk's Lambda) not explained by differences between groups. Table 4 displays the results correctly classified in depressed male patients.

However, when discriminant analysis was conducted with only female gender, the results show a lower association between laughter and Hamilton's score value. Thus, although for female patients the first two discriminant functions are statistically significant ($p < 0.001$) explaining a cumulative percentage 69.56% of the variance, the overall percentage of cases correctly classified was only a 66.17%. In contrast with male patients, a low value of the canonical correlation in the first (0.65) and second (0.54) discriminant functions was obtained indicating a low relationship between the group membership and discriminant function values. Compared with male gender (Table 4), only a 66.17% of depressed female patients were correctly classified.

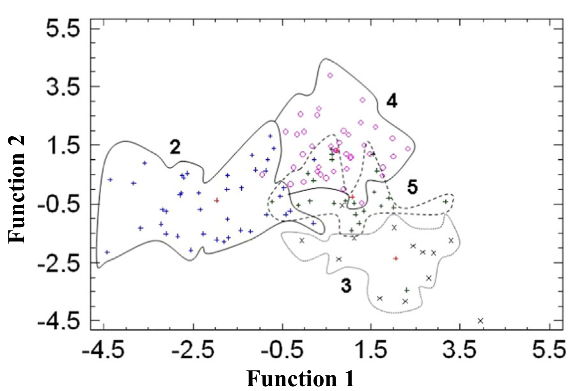

Fig. 3. Laughter discriminant analysis of male depressed patients and HDSR classification. Score intervals of 8–13 (slight depression), 14–18 (moderately depression), 19–22 (severe depression) and greater than 23 (hard depression) recorded as 2–5 classes respectively (1 class is not included since it corresponds to 0–7 or normal).

Table 4
HDRS male classification table.

Groups	*Cases*	(%)
2	35 of 41	85.37
3	10 of 13	76.92
4	36 of 40	90.00
5	19 of 23	82.61

Overall: 85.47% cases correctly classified.

4. Discussion

This study aimed at establishing a relationship between laughter sound structures and depression severity, suggesting the possibility of using laughter analysis as a new tool for clinical diagnostic and evaluation of depression. To the best of our knowledge, this is the first time that laughter itself is proposed in diagnosis beyond its widespread use as a therapeutic tool in alternative medicine and in some psychiatric frameworks—indeed, laughing therapies are quite natural a method, long ago used for the prevention and treatment of psychological disorders and mental illnesses (Gelkopf, 2011; Walter et al., 2007; Martin, 2002).

Our results suggest that the sound structures of laughter – plosives, tones, entropy, and other variables – may be systematically involved not only in providing social contextualization and individual distinctiveness (Bachorowski and Smoski, 2001), but also in encoding and distinguishing the underlying emotional states in interpersonal relationships (Marijuán and Navarro, 2011). In consequence, in the extent to which this correlation holds and successive experimental results might confirm and refine the hypothesis, laughter could be used as a *bona fide* medical indicator of well-being and mental health (Hasan and Hasan, 2009), as well as a diagnostic tool in the onset and evolution of relevant neuropsychiatric pathologies—extending what we have explored about depression herein.

The fact that based on the analysis of laughter we have been able to successfully classify about 88% of depressed patients could be explained because these patients are affected by a humour deficit and by increasing feelings of anhedonia. Interestingly, in depressed patients anhedonia has not effect on visual joke comprehension (Corcoarns et al., 1997). Likewise schizophrenia patients and also depressed patients exhibit a tendency to find the “theory of mind” jokes more difficult to understand (Corcoarn et al., 1997; Marjoram et al., 2005), which could have an effect on the sound structures of the produced laughter. Further, some symptoms of schizophrenia are also characteristic of depression compromising the same cognitive mechanism, while in other patients, such as Alzheimer, and psychotic patients, the effects on laughter may be sensibly different (Falkenberg et al., 2007).

Complementing the sound analysis of laughter with the image analysis of the associated facial expressions would add a new information layer that could be quite significant in order to gauge differences between pathologies (Uekermann et al., 2008; Falkenberg et al., 2007). However, a given stimulus, i.e. laugh videos, might lead to a burst of laughter, to a gentle smile, or to no emotional expression at all—depending of the social context and personal background. According to Parvizi et al. (2001) there is an important role attributed to the cerebellum ‘automatically' adjusting expressive behaviours according to specific environmental and social contexts. It is important to note that in our experiments we could not completely remove the social context because spontaneous laughter is in general a social signal; but we somehow generalized the social conditions by recording from each participant in an isolated room with only a single accompanying person, preferably a close friend (or a relative).

Another important methodological problem relates to the nature of the humour standards and questionnaires. Bennett and Lengacher (2008) carried out experiments supporting a connection between sense of humour and self-reported physical health, and they remarked the difficulty to determine the relationship with any specific disease process, because the outcome strongly depends on the selected sense of humour and the questionnaire scale used. We propose that the sound analysis of laughter might be an alternative approach to solve this scale problem, if not in a direct way, it would open at least the possibility of establishing some more generalized standards through videos and images related to universals of behaviours, such as falls, visual jokes, schadenfreude, etc.

A very intriguing result of this research is the remarkable gender difference in the correlation between the Hamilton test and laughter: 85.47% agreement in males, versus 66.17% in women. In the statistical analysis of males, three discriminant functions were obtained. Considering only the first discriminant function we found that many of the standardized coefficients with highest weight corresponded to the fifth plosive. That is, the fifth becomes the most discriminant plosive, explaining the correlation between the Hamilton test and laughter throughout the high discriminating power of the second formant, entropy, and energy in the afore mentioned plosive. It means that the way laughter is finalized becomes quite revealing a trait in men. Conversely, in the discriminant analysis of women, four discriminant functions were obtained. According to the values of the standardized weights in the first discriminant function, all plosive variables seem to share an equal influence on the classification. Of course, these results strictly correspond to data analysis, and other behavioural and cognitive explanations have to be contemplated. Beyond the limitations of the present study, two factors may be initially considered –or better, speculated with. On the one side, the pathology itself has a gender bias, and is somehow felt differently: a number of studies have shown that the prevalence is twice in females and that the symptom patterns exhibited by men and women are also relatively different. On the other side, both humour and laughter show considerable gender differences (Provine, 2000): as a social tool, laughter seems to be a form of social support for women, while for men it involves a more varied set of situations, apparently keeping a higher appreciation for humour production. Both kinds of factors would contribute to produce aggregate gender differences. Besides, neuroanatomical differences might be invoked: some recent neuroimaging studies on brain connectivity reveal important sex differences in the structural connectome of the human brain (Ingalhalikar et al., 2014); while another recent brain imaging study shows that different types of laughter specifically modulate connectivity within distinct part of the laughter perception network, irrespective of task instructions (Wildgruber et al., 2013). No wonder that specific gender differences in brain connectivity might be found regarding laughter production in different social circumstances of the individual. In any case, the gender differences found in the correlation between laughter and depression are a curious outcome of our study that deserves further research on its own.

In sum, research on laughter is not only intriguing intellectually, but it is also socially relevant. Because of its multidisciplinary allure, behavioural and relational importance, and health beneficial effects for patients, there will always be a plethora of studies focusing in the therapeutic use of humour and laughter. But the current gap between clinical practice and scientific research will be maintained unless more rigorous work both empirically and methodologically is undertaken. We believe that our approach to the sound structures of laughter in depression may represent true advancement in that direction, with potential to be applied to the diagnosis of other mental illnesses and relational frameworks. This is a proof of concept study. To facilitate the clinician use of a laughter analysis test, we are planning the development of a software to record and analyze laughter and, based on the laughter variables described in methods section, it would give the clinician a probability (in percentage) of suffering a depression.

Thus, the continuation of this line of research could show that laughter is not merely an idiosyncratic element to be tolerated in some psychiatric frameworks and clinical settings, benevolently considered as part of alternative medicine. Rather, we propose that it could be incorporated into evidence-based medicine along with conventional methods of diagnosis of depression.

4.1. Limitations

(i) A library of laughs was obtained through previous compilation of humorous videos selected to evoke laughter in all kinds of people, irrespective of age, mood, cultural background, etc., implying thus quite variable chances of laughter production and modulation. (ii) It is not easy for subjects to feel comfortable and laugh naturally when a recorder is capturing all the sounds and expressions. (iii) Evaluating whether a laughter episode was suitable or not depended on personal inspection of the records, since this task is difficult to achieve with automatic laughter detectors. (iv) The sample size was relatively small and may not be representative of the depression general population.

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Conflict of interest

There is no conflict of interest.

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References

Adams, P., 2008. Humor and health. Int. J. Psychother. 12, 21–23.
Ariniello, L., 2001. Brain Briefings. Humor, Laughter and the Brain. Society for Neuroscience, Washington.
Attardo, S., 1994. Linguistic Theories of Humor. Walter de Gruyter, Berlin.
Bachorowski, J.A., Smoski, M.J., 2001. The acoustic features of human laughter. J. Acoust. Soc. Am. 110, 1581–1597.
Bachorowski, J.A., Owren, M.J., 2002. Vocal acoustics in emotional intelligence. In: Feldman Barrett, L., Salovey, P. (Eds.), The Wisdom of Feelings: Psychological Processes in Emotional Intelligence. Cambridge University Press, New York, pp. 11–36.
Bennett, M.P., Lengacher, C., 2008. Laughter May Influence Health: III. Laughter and Health Outcomes. eCam. 5, 37-40.
Corcoarns, R., Cahill, C., Frith, C.D., 1997. The appreciation of visual jokes in people with schizophrenia: a study of ‘mentalizing’ ability. Schizophr. Res. 24, 319–327.
Dupont, S., Dubuisson, T., Mills, J.A. et al., 2009 LaughterCycle. QPSR of the Numediart Research Program 2, 2.
Falkenberg, I., Klügel, K., Bartels, M., Wild, B., 2007. Sense of humor in patients with schizophrenia. Schizophr. Res. 95 (1–3) (259-61).
Freud, S., 1928. Humor. Int. J. Psychoanal. 9 (1), 1–6.
Gelkopf, M., 2011. The use of humor in serious mental illness: a review. Evidence Based Complement Altern. Med 17, 1–8.
Hasan, H., Hasan, T.F., 2009. Laugh yourself into a healthier person: a cross cultural analysis of the effects of varying levels of laughter on health. Int. J. Med. Sci 6, 200–211.
Hurley, S., Dennett, D.C., Adams, R.B., 2011. Inside Jokes: Using Humor to Reverse-Engineer the Mind. The MIT Press, Cambridge (MA).
Ingalhalikar, M., Smith, A., Parker, D., Satterthwaite, T.D., Elliott, M.A., Ruparel, K., Hakonarson, H., Gur, R.E., Gur, R.C., Verma, R., 2014. Sex differences in the structural connectome of the human brain. Proc Natl Acad Sci U S A 111 (2), 823–828.
Marijuán, P.C., Navarro, J. 2011. The Bonds of Laughter: A Multidisciplinary Inquiry into the Information Processes of Human Laughter. arXiv:1010.5602v1 [q-bio.NC].
Marjoram, D., Tansley, H., Miller, P., et al., 2005. A theory of mind investigation into the appreciation of visual jokes in schizophrenia. BMC Psychiatry 5, 12.
Martin, R.A., 2002. Is Laughter the Best Medicine? Humor, Laughter, and Physical Health Current Directions in Psychological Science December 11(6), 216-220.
Martin, R.A., 2006. The Psychology of Humor: An Integrative Approach. MA & Amsterdam Elsevier Academic Press, Burlington.
Parvizi, J., Anderson, S.W., Martin, C.O., Damasio, H., Damasio, A.R., 2001. Pathological Laughter and Crying: A Link to the Cerebellum Brain 124(9), 1708-1719.
Penson, R.T., Partridge, R.A., Rudd, P., et al., 2005. Laughter: the best medicine? Oncologist 10, 651–660.
Poeck, K., 1985. Pathological laughter and crying. In: Frederick, S. (Ed.), Handbook of Clinical Neurology, vol I. Elsevier, Amsterdam.

Portmann, J., 2000. When Bad Things Happen to Other People. Routledge, London.
Provine, R.R. 2000. Laughter: A Scientific Investigation. In: Faber & Faber. (Eds.), London.
Ramos-Brieva, J.A., Cordero-Villafafila, A., 1988. A new validation of the Hamilton Rating Scale for Depression. J. Psychiatr. Res. 22 (1) (21-8).
Rozengurt, T.R., 2011. Neuroscience of humor processing: a selective review. Res. J. Humor Stud. 1, E72–E78.
Sheehan, D.V., Lecrubier, Y., Sheehan, K.H., et al., 1998. The MINI-international neuropsychiatric interview (MINI): the development and validation of a structured diagnostic psychiatric interview for DSM-IV and ICD-10. J. Clin. Psychiatry 59 (suppl. 20), 22–33.
Suls, J.M., 1972. A two-stage model for the appreciation of jokes and cartoons. In: Goldstein, J.H., Mcghee, P.E. (Eds.), The Psychology of Humor. Academic Press, New York.
Trouvain, J. 2003. Segmenting phonetic units in laughter. In: Proceedings of ICPhS, Barcelona.
Uekermann, J., Channon, S., Lehmkämper, C., Abdel-Hamid, M., Vollmoeller, W., Daum, I., 2008. Executive function, mentalizing and humor in major depression. J. Int. Neuropsychol. Soc. 14, 55–62.
Walter, M, Hänni, B, Haug, M, et al., 2007. Humour therapy in patients with late-life depression or Alzheimer's disease: a pilot study. Int. J. Geriatr. Psychiatry 22, 77–83.
Wild, B., Rodden, F.A., Grodd, W., et al., 2003. Neural correlates of laughter and humor. Brain 126, 2121–2138.
Wildgruber, D., Szameitat, D.P., Ethofer, T., Brück, C., Alter, K., Grodd, W., Kreifelts, B., 2013. Different Types of Laughter Modulate Connectivity within Distinct Parts of the Laughter Perception Network. PLoS ONE 8 (5).