Artificial Neural Network models (ANNs) in identifying Idiopathic Normal Pressure Hydrocephalus (INPH) and Alzheimer Dementia (AD) patients:

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Case Report

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Abstract

Idiopathic Normal Pressure Hydrocephalus (INPH) patients present symptoms common to other diseases, as dementia (AD). However, while dementia is not reversible, INPH dementia can be treated through neurosurgery.

The perception characteristics of a small sample of patients (n=19) were observed through the Rorschach Inblok test. Artificial Neural Networks (ANNs) models allowed to analyze the correlations between patients’ cognitive functions and perception characteristics.

The results obtained lead to interesting remarks about the independent traits in pattern of response to patients with INPH and AD. In performing the test, the latter concentrated more on the cards displayed and what they perceived, while other patients concentrated on reactions related to the image proposed. The Rorschach test can be a valid predictor tool to identify INPH patients, who could successfully be treated with neurosurgery. Hence, this methodology show its potentialities on differential diagnosis applied in clinical context.

1. Introduction

Idiopathic Normal Pressure Hydrocephalus (INPH) is a brain disorder characterized by the enlargement of the brain ventricular system while the cerebrospinal fluid (CSF) pressure remains within the normal range. INPH mainly affects men over 65 years of age: it is a progressive, chronic disorder, causing cognitive impairment, without a specific identifiable cause [1]. The idiopathic form must be distinguished from other chronic forms of hydrocephalus conditions, which can derive from brain surgery, meningitis, or head injury in 50% of cases [2].

INPH is characterized by ventricular enlargement without intracranial hypertension which expresses clinically gait disturbances, urinary incontinence, and dementia (known as the “Adams triad”), and accounts for 2–10% of all forms of dementia and 40% of adulthood hydrocephalus.

The classic triad appears like other neurological conditions, such as Alzheimer Dementia (AD) [1]. However, while dementia is not reversible, INPH dementia can be treated through neurosurgical procedures, by installing a shunt to drain excess CSF into another part of the body: this treatment may reverse the symptoms and restore the normal hydrocephalus functioning [3].

In fact, after treatment, clinical improvements have been reported in 30–96% of patients [4]. It was found that 93% of patients have gait improvements and more than 50% have significant cognitive improvements [5, 6].

Despite the large amount of data available, some aspects concerning the differential diagnosis between other forms of dementia and the accuracy of patients’ selection for ventriculo-peritoneal shunt are still controversial [7].
INPH is a real challenge for the medical community [8]: it is extremely difficult to differentiate INPH and AD based on the neurological deficits and/or considering clinical evidence only, as measuring ventricular size through conventional medical imaging techniques [9]. The distinction is clinically important because INPH, as it has been said, is one of the few treatable causes of dementia [10].

Hence, the main costs of INPH derive from the lack of diagnosis of the disease: the estimated annual cost for patients not treated due to a lack of diagnosis is € 1.695mln. Moreover, since there is no formal definition of INPH, this circumstance causes discrepancy in estimating its real incidence, that is thought to range from 2 to 20 per million/people per year. The difficulty of distinguishing INPH from other neurodegenerative disorders is the likely reason why about 80% of cases remain unrecognized and untreated [11]. Although data report 5/100,000 new cases diagnosed every year, the real number of people with INPH is supposed to be higher. A percentage ranging from 9 to 14% of the elderly living at home present INPH symptoms and a further increase in the number of people suffering from this disease can be assumed considering population aging [12].

An accurate diagnosis is necessary because conventional hydrocephalus treatments have no benefit in the non-hydrocephalus patients: if non-hydrocephalic patients are misdiagnosed as hydrocephalic patients, treatment have been shown not only to be ineffective, but are associated with significant morbidity and likely increasing costs [13].

In the light of these considerations, since the overall prevalence of dementia rises progressively as the population ages, even if INPH is responsible for only a small proportion of senile dementia, successful treatment could help many patients [14]. They could be treated in a short time with savings of resources; costs due to wrong therapies or inappropriate diagnostic procedures would be lower and patients’ quality of life would be higher.

About the type of treatment and assistance, the spontaneous course of INPH requires, for most patients, to rely on nursing care [15]. For those patients undergoing surgery, continuous and regular checks by the neurosurgeon are required, to ensure that the shunt is working properly [16]; continuous follow up and assistance can be complemented with physiotherapy treatments, socialization and psychological support.

A comprehensive estimation of INPH costs has not been performed so far: in 2000, hence, more than two decades ago, the costs of treating INPH, in the US, exceeded $1 billion: there were 27,870 patients with INPH treated, and more than 8,000 were new cases diagnosed; however, updates should be necessary [17].

Together with considerations of costs, another field of analysis is the implementation of new diagnostic tools. To our knowledge, no clinical or neuroradiological techniques have been validated to clearly identify dementia from INPH, as both share anatomical and clinical similarities [18]. Magnetic resonance imaging (MRI) depicts ventricle size accurately: however, findings on brain images are not sufficient, on
their own, to establish a diagnosis because they provide minimal, if any, evidence of brain damage, despite marked deficits in motor skills and cognitive functioning [10, 19, 20].

In a study describing advantages and drawbacks of MRI parameters it has been stressed the importance to find specific imaging biomarkers likely to distinguish the two conditions [21]. If a screening tool may identify possible cases, then further workup could be done to confirm the diagnosis and determine the need for shunting [22–24].

The Rorschach test is usually considered in psychological diagnosis, clinical, personality assessment and selection context for the detection of the global personality profile in the pattern of response [25–29]. The response process of inkblot is centered on the identification of the mental function, cognitive pattern and characteristic traits of the personality [30, 31]. The answers to the questions posed through the perceptual task could get pattern of cognition, also visual-perception, language process or inhibition of the phases of the response process [32–35].

Despite the pioneering nature of the present study, its results have to be appreciated and carefully considered, since they allow to identify the common traits and pattern of response to INPH patients and AD.

Hence, this study is aimed at assessing the Rorschach method as a valid tool to recognize INPH patients. The information collected by administering the test have been analyzed through the implementation of three different methods: Population, Self-Organizing Maps (SOM), Artificial Neural Networks (ANNs). Characteristics of INPH vs. AD patients have then been outlined and commented. Some comments on the advantages of adopting the Rorschach test in such a complex diagnosis will conclude the study.

### 2. Materials and Methods

A small sample of patients (n = 19) was observed at the Polyclinic of Messina, Southern Italy, in the year 2015. Eleven patients suffered from INPH, while the remaining eight patients presented dementia from AD. The observed patients (or their caregivers) gave their written informed consent, and the study protocol was approved by Ethical Committee Policlinico AOU Messina Observational Study n. 28-219.

The study was carried out according to the Declaration of Helsinki.

Two psychological tests were carried out.

The patients’ mental status was measured through the Mini Mental State Examination (MMSE) [36] an 11-item questionnaire testing the areas of cognitive function (orientation, registration, attention, calculation, recall and language): a low score is indicative of cognitive impairment.

The perception characteristics and personality traits were observed instead, through the Personality Rorschach Inkblot test [37, 27, 29, 38-40]. The test consists of 10 symmetrical Inkblot: 5 monochrome, 2 two-tone and 3 coloreds. The images are brought to the attention of the subject, one by one; there is no
time limit imposed and for each response the interpretation looks at the characteristics of each image, i.e., form, content, and the determinants, codified in the form, color, shading, movement [41-44]. The coding of the responses is based also on the time to provide or refuse an answer and any additional comments [29,31].

The information provided on the general aspects of the inkblot (shape, color, etc.) and the location (such as its details), are often considered more important than the content itself; considering the originality of the response, this is considered positive or negative (+ or -), in relation to good and poor form [38]. Considering the theme of the image, the content human, natural, animal, abstract etc., is classified in categories according to the frequency of the interpretation [27, 29, 37]; the emotional life of the subject is centered on the colors and its shading [42, 44].

The literature provides example of the clinical application of the inkblot task, in the sample of elderly subjects or suspected dementia patients [31,32] and for differential diagnosis of brain impairment [45,46]. Organic signs were also observed in brain subcortical and cortical involvement, also in the cognitive deficiency in the performance that occurs in organic lesion [34, 45, 47-48]. The Inkblot task reveals ability to detect perceptive and visuo-spatial function in a neuropsychological perspective of the clinical assessment [49-51].

The information collected from the administration of the Rorschach Inkblot Test has then been analyzed through computational methods applying different algorithms.

These methods are:

- **Populations**: it is a Multi-Dimensional Scaling algorithm that projects the observed individuals on a bi-dimensional plane with coordinates X and Y [52];
- **Self-Organizing Map (SOM)**: it is an unsupervised neural network clustering the observed individuals focusing on input variables on a bi-dimensional matrix [53];
- **Auto Contractive Map (AutoCM)**: it is an unsupervised neural network that detects the existing relationships between variables based on the values that is possible to attribute to each individual; the results can be represented through a graph (the *Maximally Regular Graph*, MRG) [54].

3. Results

The descriptive statistics of the examined sample can be observed in Table 1.
<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Std. Dev.</th>
<th>Min</th>
<th>Max</th>
</tr>
</thead>
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<tr>
<td>Age</td>
<td>76.11</td>
<td>7.32</td>
<td>59</td>
<td>88</td>
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<tr>
<td>Age &gt; 75</td>
<td>0.58</td>
<td>0.51</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Gender (1 = female; 0 = male)</td>
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<td>0.51</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Compulsory education</td>
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<td>0.50</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Married (1 = yes; 0 = no)</td>
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<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
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<td>Number of answers</td>
<td>10.32</td>
<td>3.83</td>
<td>4</td>
<td>18</td>
</tr>
<tr>
<td>MMSE total score</td>
<td>17.89</td>
<td>5.15</td>
<td>8</td>
<td>27</td>
</tr>
<tr>
<td>Localization:</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global (G)</td>
<td>5.42</td>
<td>2.81</td>
<td>1</td>
<td>13</td>
</tr>
<tr>
<td>Details (D)</td>
<td>4.58</td>
<td>3.06</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>Little details (Dd)</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Localization: details→globals (DG)</td>
<td>0.21</td>
<td>0.71</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Determinants:</td>
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<td></td>
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<td></td>
</tr>
<tr>
<td>$F$ (shape)</td>
<td>8.53</td>
<td>4.14</td>
<td>2</td>
<td>16</td>
</tr>
<tr>
<td>$F^+$ (positive shape)</td>
<td>5.63</td>
<td>3.20</td>
<td>1</td>
<td>12</td>
</tr>
<tr>
<td>$F^-$ (negative shape)</td>
<td>2.89</td>
<td>2.21</td>
<td>0</td>
<td>8</td>
</tr>
<tr>
<td>$M$ (Human kinesthetic activity)</td>
<td>0.74</td>
<td>1.24</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>$FM$ (Animal kinesthetic activity)</td>
<td>0.05</td>
<td>0.23</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>$m$ (inanimate movement)</td>
<td>0.05</td>
<td>0.23</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>$CF$ (color and shame)</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>$FCho$ (diffuse shading)</td>
<td>0.05</td>
<td>0.23</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>$Cho$ (pure shading)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>-------</td>
<td>-----------</td>
<td>-----</td>
<td>-----</td>
</tr>
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<td>Contents:</td>
<td>5.84</td>
<td>2.59</td>
<td>0</td>
<td>10</td>
</tr>
<tr>
<td>A (animals)</td>
<td>0.47</td>
<td>1.02</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Ad (animals details)</td>
<td>1.26</td>
<td>1.48</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>H (Human)</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>(h) (fantastic human)</td>
<td>0.37</td>
<td>0.83</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Hd human details</td>
<td>0.95</td>
<td>1.31</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Obj object</td>
<td>0.16</td>
<td>0.37</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Cibo food</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Nat nature</td>
<td>0.58</td>
<td>0.96</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Botanic</td>
<td>0.32</td>
<td>0.75</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td>Anatomical</td>
<td>0.05</td>
<td>0.23</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Smoke</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Cartoon</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Art</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Popular</td>
<td>2.21</td>
<td>1.17</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>Original</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>TRI I (Erlebniss typus I)</td>
<td>1.74</td>
<td>0.99</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>TRI II (Erlebniss typus II)</td>
<td>2.16</td>
<td>0.96</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>IR (reality index)</td>
<td>3.58</td>
<td>1.80</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>Particular phenomena</td>
<td>0.37</td>
<td>0.50</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Perseveration</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inadequacy</td>
<td>0.21</td>
<td>0.42</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Insecurity</td>
<td>0.26</td>
<td>0.45</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Stereotyped</td>
<td>0.05</td>
<td>0.23</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Refuse</td>
<td>0.63</td>
<td>0.50</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Confabulation</td>
<td>0.21</td>
<td>0.42</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Abstraction</td>
<td>0.05</td>
<td>0.23</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Contamination</td>
<td>0.05</td>
<td>0.23</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Variable</td>
<td>Mean</td>
<td>Std. Dev.</td>
<td>Min</td>
<td>Max</td>
</tr>
<tr>
<td>-------------------</td>
<td>------</td>
<td>-----------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>Difficulty of naming</td>
<td>0.05</td>
<td>0.23</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Self-reference</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Devitalization</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sensation</td>
<td>0.11</td>
<td>0.32</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

The mean age of the observed patients was 76 years old (min 59 years, max 88 years old). The sample included 11 males and 8 women; all male patients but one suffered from INPH. Twelve patients were older than 75 years and 89% were married. The average number of answers was 10.32 for ten table (min 4, max 18).

In spite of the small number of subjects in the sample, the methods employed for the analysis, as it will be seen, allowed to cluster the two groups of patients.

### 3.1 Results with *Populations*

In Table 2, the input data employed in the calculations carried out with *Populations* are shown. On each line, the 19 subjects (also called “cases” or “records”) are reported; on each column there are the 45 variables employed.
Populations ordered the 19 subjects on a two-dimensional plane. Each subject is, therefore, represented by the point with coordinates x, y. The distance between the points is the difference between the values of the 45 variables in the records.

The distribution obtained shows that, except for a subject (we will call this patient “dementia 1”), the system has distinguished the two populations of patients (Fig. 1).

Hence, according to this algorithm, the variables included in the analysis are sufficiently relevant to identify the two types of subjects.

### 3.2 Results with SOM algorithm

A SOM has been set up with an output matrix measuring 5x5, therefore it is potentially possible to obtain 25 classes.

Given the reduced number of records (19) out of 25 “virtual” classes, SOM has located each subject in a class. Only in one case two subjects share the same class (in the output, this is class 5.2; the subjects are INPH9 and INPH7).

In Fig. 2, it can be noted how the two populations have been distributed in different areas of the matrix.
This result confirms the indication obtained with *Populations*; therefore, the 45 variables are a good indicator to distinguish the two pathologies, INPH vs AD. More specifically, when processing the data, it has been seen how some variables, among which there are, for example, the determining variables “Global”, “Detail”, “Form”, “Good form”, etc., do not show a specific distribution. Instead, other variables, such as “Form over diffuse shading”, “Original”, “Original characterized by good form”, “Inadequacy”, show a high value only in some classes.

### 3.3 Results with *AutoCM*

Lastly, the AutoCM model is helpful to understand the relation between each variable and the two populations of patients.

The web input has been set up, apart that with the same 45 variables of the two previous experiments, also by adding two variables that discriminate subjects according to their pathology (see last column of Table 3), and that, in the graphical representation, will allow to highlight the characteristics of the two pathologies.

**Table 3.** The data set used as input of the AutoCM network. On the rows, there are the 19 subjects, on the columns, there are the 47 variables employed.

![Table 3](image)

The AutoCM has learnt the records made by the 19 subjects. Every layer of the web (input, hidden, output) was composed by 47 units. When processing is finished, the most relevant connections among the 47 variables have been highlighted by the MRG graph.

Figures 3 and 4 show the graphs obtained with the ANNs, respectively, without and with the values of the relations among variables. Some variables connected to Rorschach’s interpretation are more closely linked to diagnosis of INPH and AD.
We can summarise the evidence emerged by these graphical representations.

For the INPH group, the most relevant variables were Animal contents (A); Form response (F); Details (D); Popular response; Adequacy of index of reality (IR).

In AD, the most relevant variables were Perseveration phenomena, Inadequacy, and Particular phenomena as Card rejection, Linguistic errors.

That means that INPH (and, consequently, patients’ behaviour) is strictly linked (connection value = 0.99) to animal forms, indicating higher emotional inhibition, to common responses (popular) and well-formed responses (connection value between popular responses and forms = 0.99). The number of responses (numero risposte), strictly linked to shape, is, in turn, connected to perception of more details in the interpretation, to well formed - responses and to the reality index.

Data shows how the structure highlighted in this typology of patients has a better adaptation to reality and perception levels are closer to average population, in comparison to psychopathological phenomena observed in AD cases (i.e., perseveration, card rejection and linguistic errors).

AD patients, instead, are more linked to phenomena highlighting the subjects’ behaviors in relation to the stimulus represented in the board (i.e., particular phenomena: for example, waste (rifuti, 0.99); subjects’ reactions as uncertainty (0.99) and perseveration (0.98). The latter is connected to inadequacy (indeguatezza) in the response.

4. Discussion and Conclusions

This study highlights the implications of using the Inkblot task in clinical practice and neuropsychological assessment for differential diagnosis with patients suffering from organic and neurodegenerative diseases, such as idiopathic normal pressure hydrocephalus (INPH) and Alzheimer’s disease (AD).

As specified in the Introduction, INPH is a syndrome characterized by gait impairment, cognitive decline and urinary incontinence, and is associated with ventriculomegaly in the absence of high cerebrospinal fluid (CSF) pressure [57]. It is different from AD, which is a chronic neurodegenerative disease that usually starts slowly and gradually gets worse over time [61].

The Rorschach method can be considered a neuropsychological tool to detect alterations of psychic functions [29, 38, 47, 49]. In other contributions, the alterations of the psychic functions have been studied in relation to memory deficits, poor emotional and impulse control, linguistic errors, and phases of the process of the response [32, 33, 35, 45]. In cognitive impairment, elderly patients demonstrated unable to synthesize perceptual details or the organization of complex forms, also centered on the deficit of the visual-perception, recognition, lack of awareness, signs of organicity [33, 47]. Unlike AD patients, INPH patients have interpretative awareness and do not make linguistic errors. Other authors highlight the
potential of the test in the neuropsychological assessment related to response process and psychic functions also perceptual processing, attention, memory and executive functioning [33, 46, 49, 50, 51].

We have seen that the first analysis technique employed (Populations) showed how the two subsamples of patients can be considered as distinct. Then, we processed data with the SOM: also this technique, in line with the studies present in literature, was a good indicator to distinguish between the two groups of patients.

Instead, the AutoCM model has been useful to understand the relationship between variables (such as Animal contents (A); Form response (F); Details (D); Popular response; Index of reality (IR)) that are strictly connected to INPH diagnosis. Variables connected to AD diagnosis can be identified in perseveration phenomena, inadequacy, particular phenomena, card rejection and linguistic errors. As far as INPH is concerned, a higher emotional inhibition can be seen found in animal responses, but a higher adaptation to reality is reported, differently from AD patients. These patients have a good adaptation to reality and perception levels closer to the average population, compared to psychopathological signs that are observed in patients with AD, i.e., rejection, perseveration process and linguistic mistakes.

Neuropsychological aspects for the patients with cognitive deficit reveal, for the difficulty on the re-enactment memory, the perseveration of the theme and low control of the pulses, usually signed C, CF or extratensive resonance, codified in the form of subjective Erlebnistypus [27, 33, 44, 46, 47].

The results obtained through the implementation of ANNs demonstrated the potentiality of the Rorschach test in identifying, even within a small sample, those patients presenting INPH. These patients concentrated more on the table displayed and what they perceived, while AD patients concentrated on personal reactions (such as particular phenomena) related to the image proposed by the test.

The group INPH did not show clear signs of organic dysfunction, as it was found specifically in people with AD. The cognitive patterns connected to AD and stated in the literature were signs of perplexity of the interpretation process, perseveration of the content, visuospatial deficit, language mistake in the response process [33, 45, 51].

These evidence shows that the Rorschach method is also a cognitive task, involving the global brain in the response process, suitable for detecting perceptual deficit, included visual perception pattern, object recognition, language production [31, 35].

The neuropsychological approach in a clinical assessment may provide a milestone for empirical research in the differential diagnosis of the clinical frame.

The neuropsychological approach based on the signs of the Inkblot task may distinguish the two different diagnoses: overall, the test may detect the mental changes linked to each of them, looking at the pattern of the cognitive functions (such as, signs of the memory impairment, recognition, emotions and control impulse, visuo-attention and executive functioning, language process).
Since it can be used with all individuals without being limited by people's education level, the test is a valid predictor task in a broader neuropsychological evaluation, able to identify cognitive pattern of the INPH patients.

The three distinct methods led to the same conclusions. Even if carried out on a small sample, the present study suggests original and innovative results in the assessment and clinical research of reversible dementia. If correctly and timely diagnosed, INPH can be corrected through neurosurgical treatment, achieving an improvement in patients’ wellbeing and quality of life, together with a reduction in the cost of illness.

Declarations

Conflict of Interest

The authors have no conflicts of interest to declare.

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None

Author Contribution

L.G.: Conceptualization, Investigation, Data Curation, Writing — original draft, Writing — review & editing, project administration; C.M.: Conceptualization, Methodology, Investigation, Writing — original draft, Resources, Supervision; G.M.: Methodology, Software, Validation, Formal Analysis, Data Curation; P.M.B.: Software, Validation; G.R.: Visualization; A.G.: Visualization; M.C.Q: Methodology, Resources. All authors reviewed the manuscript.

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Figures
Figure 1

Results with \textit{Population} algorithm

Figure 2

Results with SOM
Figure 3

MRG graph obtained analysing the connections between hidden and output units of the ANNs.
Figure 4

MRG graph obtained by analysing the connections between hidden and output units of the ANNs (with indication of each value)

Supplementary Files

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- Appendix.docx