Physiological Data Stream Analytics to Evaluate Noxious Stimuli in the Newborn Infant.

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INTRODUCTION

Research to understand pain perception, nociceptive stimulus and physiological stress response in an immature organism, such as the premature newborn infant, has taken place over the last 40 years. Lowery et al. [1] demonstrated that while a fetus develops in utero or a premature newborn develops after birth, they are not able to perceive pain, but perceive nociceptive stimuli to create a neurological path in response to pain. Furthermore, Brummelte et al.[2] showed a direct association between pain and maturation of neurological structures. Beyond Brummelte's findings, Anand[3] found a correlation between early pain experienced in a neurologically damage brain in animal studies. Our aim was to correlate non-invasive physiological variables that describe a pain response and based on the correlation deploy a neural network capable of identifying a pain pattern in the Neonatal Intensive Care Unit (NICU).

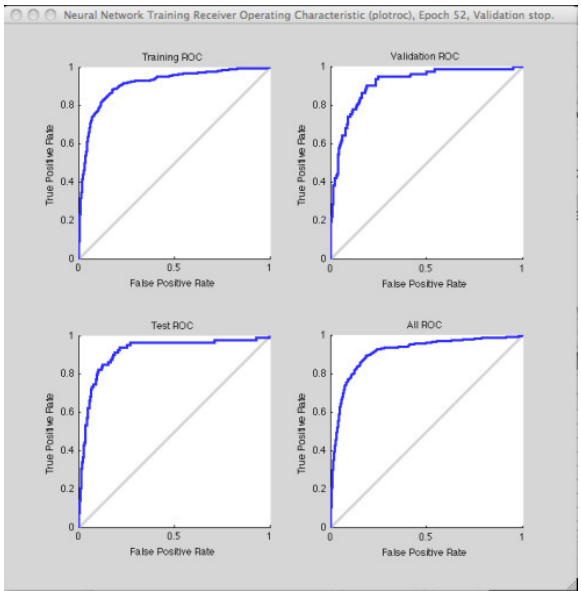
METHODS

The Neural Networks (NN) technique was considered appropriate to identify a behaviour pattern considering the complexity and non-linearity of the physiological data. The pattern recognition category of NN was used to learn from input-output relationships and use sequential training procedures to adapt to the data. In order to optimise the development of the NN to generate the intelligent alerts, a Radial Bias Function (RBF) was selected to implement the NN. Three male, preterm infants, gestational age 27.25±0.95 weeks, birth weight 941.25±189.31 grams, were randomly selected for this study from patients enrolled in the Artemis study. Artemis is a framework for concurrent multi-patient, multi-diagnosis and multi-stream temporal analysis in real-time for clinical management and research.[4] Heart rate (HR), mean arterial pressure (MAP), Respiratory Rate (RR) and blood oxygen saturation (SpO_2) were considered for the NN Input Vector. Noxious stimuli were defined when the simultaneous occurrence of:

$$HR \geq 160 \; AND \; MAP \geq 55 \; AND \; RR \geq 40 \; AND \; SpO_2 < 90$$

When this pattern was recognized by the NN the output vector should be otherwise.

RESULTS



Data from different periods of the patient stay in the NICU were considered. The data training set comprised 7000 lines from patient 1 including physiological data in both normal and abnormal conditions. Figure 1 shows the result of the NN after testing:

Figure 1- ROC graph from NN tested with 7000 lines from patient 1.

Considering the good performance of the NN a second physiological data set from a different patient was inserted into the NN to test its performance. The NN

performed fairly in the recognition of noxious pattern for patient 2 as shown in figure 2a. Data collected from a third patient, patient 3 was used in the NN presenting an excellent performance as shown in figure 2b.

a)

b)

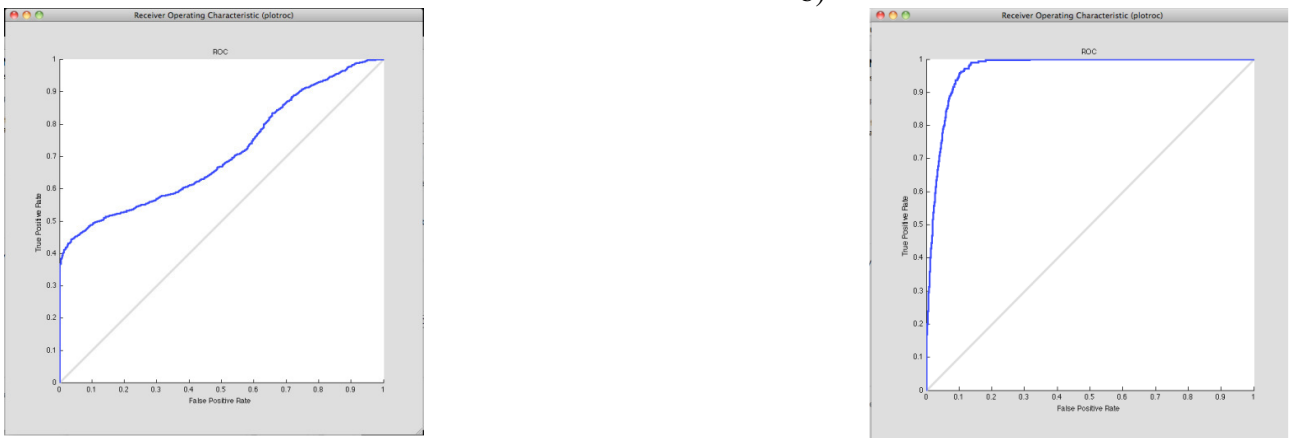


Figure 2 - NN tested with two different patients.

DISCUSSION

The Receiver Operating Characteristic Curve (ROC) from Figure 1 shown that training, testing and validation with the first patient's data set performed well, placing the NN as very good. When patient 2 was inserted to test the NN the result was a fair prediction of the noxious pattern, however patient 3 demonstrated a perfect prediction of the pattern resulting in an excellent NN. Although all three patients were preterm infants, patient 2 had experienced severe intrauterine growth restriction. The infant's small head circumference indicates that brain growth has been impaired and suggests that development and/or maturation of the brain is abnormal. Therefore, considering Anand and Brummelete findings and our own findings with a physiological data set to determine noxious stimuli, leads to the conclusion that brain development and damage are intrinsically correlative to pain stress response and is a deterministic factor to determine pain in preterm infants and their relation with pain later on in adult life.

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