The Design of a Respiratory Rate Mobile Application

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Introduction: Respiratory rate (RR) is an essential vital sign, yet its manual assessment is often inaccurate[1]. The recommended method for measuring RR is counting the number of breaths in a minute. In a busy clinical setting, this is a significant period of time to be focused on counting breaths. Any disruption means the minute must be restarted. We have designed a smartphone application, called *RRate*, to provide a more efficient measurement of RR with clinically acceptable accuracy for the diagnosis of fast breathing in children. The user taps the touch screen of the phone each time the patient inhales and the RR is calculated iteratively from tap intervals. If the taps are sufficiently consistent, the RR is displayed.

Methods: Two iterative processes were involved in the *RRate* development: the user interface design and the optimization of the tap consistency algorithm. *RRate* requires a minimum number of taps **n** that are timed within a maximum deviation percent **c** from the median between-taps time interval. The RR calculation considers the **n-1** time intervals between the most recent **n** taps. The median of these time intervals **M** is calculated and a consistency range defined as **M ± (c * M)**. If all n-1 intervals are within the consistency range, the animation is displayed and the RR of **60/M** breaths per minute is shown. If this test fails, more taps are recorded.

The user interface consists of the following elements: 1) *The touch screen* where the user taps each time the patient inhales; 2) *Audio feedback* to the user when they are observing the patient's breathing. *RRate* emits a breathing sound upon each tap. Chimes sound when the tap consistency algorithm has been satisfied and a RR is successfully calculated. After the chimes, *RRate* continues to emit breathing sounds at the calculated RR; 3) *An animation* of a breathing baby is displayed once the RR is calculated, breathing at the calculated RR (Figure 1). The user can compare the *RRate* animation and breathing sounds to the patient's breathing to confirm that the correct rate has been obtained; and 4) *A visualization* of the timing of the taps (Figure 1) that provides feedback on why the tapping was rejected or accepted. Each tap is a blue circle that is either consistent with the median of the most recent taps (green zone) or too fast or too slow (red zones).


Figure 1: RRate user interface successfully measuring RR in 6 taps.

We performed a study with 30 adult subjects using *RRate* to measure the RR of children in 10 standard videos. RRate was configured to accept taps for a minute. The collected data was used to determine the optimal choice of the **n** and **c** parameters.

Results: The choice of **n** = 5 taps and consistency **c** = 13% provided the best trade-off between efficiency and accuracy, yielding a mean time to complete of 9.9 seconds and a normalized root mean square error of 5.6%. This corresponds to 2.2 breaths/min at a RR of 40 breaths/min[2], the threshold for fast breathing in children

[1] P.B. Lovett, et al., "The vexatious vital: Neither clinical measurements by nurses nor an electronic monitor provides accurate measurements of respiratory rate in triage", *Annals of Emergency Medicine*, 2005; 45:1 68–76.

[2] W. Karlen, H. Gan, et al., "Improving the accuracy and efficiency of respiratory rate measurements in children using mobile devices", *PLOS ONE*, Submitted November 19, 2013.

[3] World Health Organization (WHO), "Pocket Book of Hospital Care for Children: Guidelines for the Management of Common Illnesses with Limited Resources", *WHO*, Geneva, 2005.
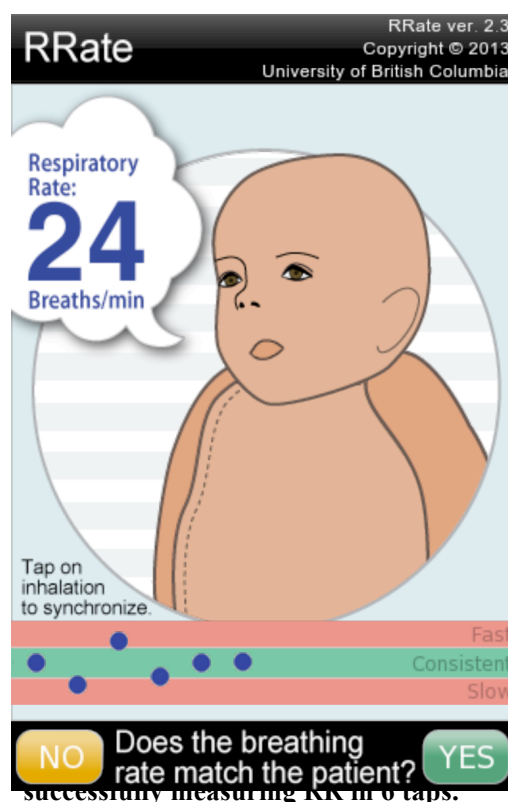
aged 1 to 5 years[3]. This study also provided valuable feedback on the user interface. The *RRate* audio was modified to its current form based on this feedback. We also added the ability to synchronize the phase of the animation to the patient's inhalation by tapping on the animation.

Conclusion: *RRate* is a simple application for efficient and accurate measurement of RR. It is available for free download on the global Google and Apple stores. It provides acceptable RR results 6 times faster than the current practice of minute-long counting. In the future, *RRate* will be used within more complex applications to aid the diagnosis and management of childhood pneumonia.