DryNights, a Self-powered Bedwetting Alarm for Children

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ABSTRACT

This extended abstract describes the concept of DryNights, a bedwetting behaviour change support system concept consisting out of a self-powered sensor and a mobile application developed in collaboration with LifeSense Group (spinoff Imec, Holst Centre) and the Eindhoven University of Technology. The sensor uses the principle of an electrochemical cell to generate its own electricity and to power a harmless and wireless signal transmission from the sensor to a mobile device. The mobile application has been designed in collaboration with children (N=75) from the target group. The reliability of the signal transmission and the range of the sensor have been successfully evaluated in a small-scale experiment. Trials with children wearing it to go to sleep are currently under way and suggest that DryNights is comfortable and children are experiencing it positively.

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KEYWORDS
Incontinence; bedwetting; alarm; self-powered; energy harvesting; electrochemical cell; solution; nocturnal enuresis; child-friendly

Redox reactions magnesium and copper

First, the dissolved oxygen in the water will "detach" the copper(II) ions, which will form copper hydroxide [7].

Half reaction:
$O_2 + 2\ H_2O\ (l) + 4e^- > 4\ OH^-$ (x1)

Half reaction:
$Cu\ (s) > Cu^{2+} + 2e^-$ (x2)

Total:
$O_2 + 2\ H_2O\ (l) + 2\ Cu\ (s) > 2\ Cu(OH)^2\ (s)$

The reaction which actually produces the electrical energy is between the magnesium and the copper ions, through the following reactions [7]:

$Cu(OH)^2\ (s) + 2e^- > Cu\ (s) + 2\ OH^-$ (x1) (0.34V)

$Mg\ (s) + 2\ OH^- > Mg(OH)_2\ (s) + 2e^-$ (x1) (-2.5V)

Total voltage difference = 0.34 + 2.5 = 2.84V

1 INTRODUCTION

Persistent bedwetting (functional nocturnal enuresis) is a common problem for more than 15% of all 5-year-olds and still 2% for 12-14-year-olds [4]. Involuntary urination at least twice a week for 5-6-years-old and once a week for children 7 years and older can be seen as enuresis [1]. Enuresis can be frustrating and embarrassing. Having to change sheets and the washing and cleaning in the middle of the night does not only affect the night's rest of the child but also of the parents [3].

The actual causes of nocturnal enuresis are quite unknown [3] but stress, genetics, constipation and hormonal problems seem to affect it [3]. Some children may produce a large amount of urine during the night due a lack of the arginine vasopressin hormone, which can cause the enuresis [3].

Also, being able to recognize when the bladder is full is a skill which has to be learned and for some children this process takes longer than normal, causing them to involuntarily urinate in bed during the night [3]. The brains of child need to recognize the signals the bladder sends as soon as it is full and contracts [3]. The brains can be trained to recognize the signals of the bladder by, while awake, either postponing (holding on) or by using the toilet [3].

2 BACKGROUND

Several solutions are known in the state-of-the-art such as diapers, drugs or behavioral and physical interventions such as rewards systems, retention control training and waking the child in the night [5]. However, these solutions are not always as effective and can have high relapse rates [5]. The most effective solution is to use a bedwetting alarm [5]. Using a bedwetting alarm, a child can overcome enuresis within about 5-12 weeks and the success rate of this treatment is between 75-90% [1].

However, many bedwetting alarms use an unfriendly buzzing sound and are fairly obtrusive, whereas several existing devices are quite large and require wires to be passed underneath the pajamas. The wireless devices often emit Bluetooth signals for communication with an external alarm module; these signals can be harmful for children who are still growing up. Also, these devices are working on expensive batteries.

2.1 Electrochemical cell

The presented inventive concept uses the principle of an electrochemical cell. Such a cell generates electrical energy due to a spontaneous redox reaction between two metals, often connected through a salt bridge [2].

3 DESIGN

DryNights is a very simple, small and cheap solution to help children overcome bedwetting during the night. The DryNights sensor does not use any batteries because it generates its own power. Rather it uses a combination of magnesium and copper, which in the presence of (salted) water or urine can

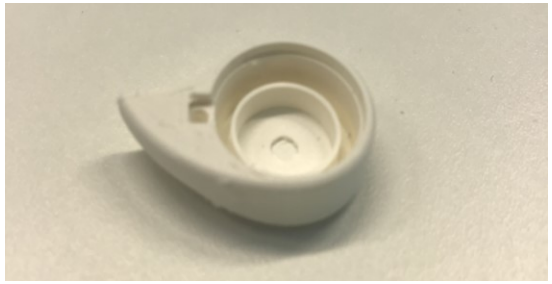

Figure 1: Acoustically designed sensor casing

Table 1: Favorable figures from the co-design sessions

Figure	Amount
Hero's	40
Animals	37
Monsters	23

Table 2: Favorable environments from the co-design sessions

Environment	Amount
Space	42
Mountain	21
Hills	22
Water	15

generate 2.84V in theory [7]. However, practical tests demonstrated that the reaction generates a substantially lower voltage of 1.5V. One of the reasons for this lower voltage may be a side-reaction which takes place on the magnesium electrode [6].

The sensor which can be easily attached to any underwear or pajama pants detects a urine leak and automatically starts sending a audial signal to the app on the mobile device. The app recognizes the sound, wakes up the child with a predetermined sound or song and automatically logs the date and time of the event. The child will interrupt the urination and continue at the toilet. If the app is also installed on the parents mobile device, they can choose to be woken in case of a urine leak as well.

The aim is that over time, the child will subconsciously shift their attention from the alarm sound to their bladder, sensing the fullness. After 5-12 weeks, the child will be conditioned to listen to the bladder signals and from then on, the child will wake up to go to the toilet instead of wetting their bed.

Other future features of the mobile application are; automatic logging of the day and time of the events, setting preventive alarms, setting goals and tracking progress and receiving rewards for e.g. going to the toilet themselves, keeping the bed dry during the night or helping to clean sheets after an accident.

3.1 Prototyping

Different prototypes of the DryNights sensor have been created (figure 3). One of the main challenges was to get the sound volume of the piezo to a level detectable by the mobile device while the sensor would be covered by blankets. The researcher has tried to combine the self-oscillating Piezo Driver Circuit with a Voltage Boost circuit to create a low-cost and small-size voltage boost circuit. However, due to several technical reasons these two circuits could not successfully be combined to increase the sound level of the speaker in the sensor.

Acoustics can significantly improve the sound level as well. Therefore, the casing of the sensor was designed for optimal acoustics (figure 2). Measurements showed an increase in sound level of 60% when using an acoustically designed casing compared to no casing.

The current prototype of DryNights comprises of a 3D printed casing including a Piezo Driver Circuit PCB, a piezo speaker and a magnesium strip. The copper of the PCB is used as one of the electrodes whereas the magnesium strip is used as the other electrode.

The designs of the mobile application and the packaging are based on the results of multiple co-design sessions together with 75 children aged 7-10 years old at a primary school. During the first session, the children were asked to draw their favorite (imaginable) figure. These figures were analyzed and categorized and used to create a new set of figures and environments which were used in the second session. In this session, the children were asked to compose their own app using the different environments and figures provided by the researcher (figure 1). Data about the preferred combinations was gathered and analyzed (table 1, 2). The most favorite figures and environments were then implemented in the final design of the app and the packaging of the sensors.

Figure 2: Co-design sessions and the result(s)

The mobile application uses an FFT algorithm to detect the 3kHz frequency peak the sensor generates.

4 EVALUATION

The range of the sensor has been evaluated by conducting an experiment in a bedroom environment. The aim of this experiment was to test the range and reliability of the DryNights sensor in different circumstances.

The independent variables were the thickness of the blanket covering the sensor and the distance between the sensor and the mobile device. The dependent variable was whether the mobile device was able to detect the signal from the sensor.

4.1 Materials

A prototype of the DryNights sensor was used to test the range of the sensors. A tablet with a simplified version of the DryNights App, including the detection algorithm was used to detect the sensor signal. Water with 1.5g of salt/100 ml was used to simulate urine. The sensor was attached to a boxer short and a syringe was used to put the salted water on the boxer short. Different blankets were used to cover the sensor. A spring rule was used to measure the distance between the sensor and the mobile device.

The thickness of the blanket is expressed in Double Blanket (2 blankets), Single Blanket, Sheet or No Blanket.

4.2 Procedure

The mobile device was placed at a predetermined distance from the sensor. The underwear was placed on the matrass of a bed and the salted water was put on the underwear using a syringe. The app was started after which the sensor was placed on the wet boxer short and covered by the blanket. If the app picked up the signal from the sensor, it provided the researcher with an alarm signal (audial and visual). The researcher kept a log about the measurements.

For each (thickness of the) blanket, at minimum of 5 different measurements were conducted. After each measurement, the mobile device was placed 50 centimeters further away from the sensor to a max of 350 centimeters.

After the measurements for all the distances were conducted, the blanket was changed after which the previously described process was repeated for the other distances. All tests were repeated three times.

4.3 Measures

The variables measured were the distance between the mobile device and the sensor, expressed in centimeters (cm). The other variable which was measured was whether the mobile device was able to detect the sound from the sensor, expressed in 0 (no) or 100 (yes).

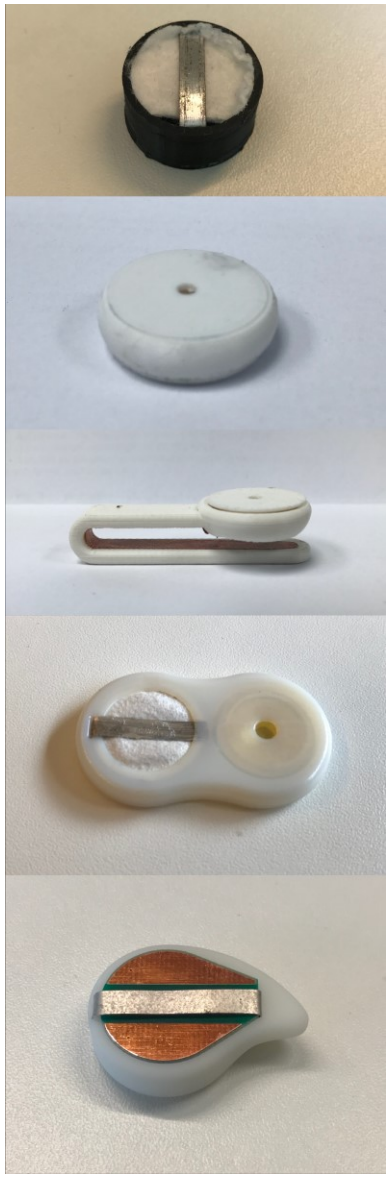

Figure 3: Prototypes of the DryNights sensor

4.4. Results

Table 3 shows the percentages of detected signals for different distances and different thicknesses of blankets.

Table 3: Combined results of 3 measurements. Showing percentage of detected signals for different distances

Distance (cm)	Double blanket (%)	Single blanket (%)	Sheet (%)	No Blanket (%)	Overall detection (%)
50	67	100	100	100	92
100	0	100	100	100	75
150	0	100	100	100	75
200	0	100	100	100	75
250	0	67	100	100	67
300	0	67	100	100	67
350	0	67	100	100	67

4.5 Discussion and conclusion

The mobile device was able to detect signals from up to 350 centimeters when the sensor was either not covered, or just covered by a single sheet. When the sensor was covered by a single blanket, all signals up to 200 centimeters were detected and 2/3th of the signal between 250 and 350 centimeters were detected.

The double blanket blocked almost all signals, except for the distance of 50 centimeters which were detected in 2 out of the 3 measurements.

When using a blanket which is thinner than a normal single blanket, all signals up to a distance of 200 centimeters will be detected and most signals between 250 and 350 centimeters as well. When using a thicker blanket, the system is not reliable.

A range of about 200 centimeters will probably be enough for this system to work. In most cases, the mobile device can be placed within 2 meters of the sensor. We, as designers of this product, should advise people how to use the product and mention the range of the sensor on the packaging. Also, the limits of the product should be mentioned, such as that it cannot be used with a specific blanket. When using a blanket which is thinner than a normal single blanket, all signals up to a distance of 200 centimeters will be detected and most signals between 250 and 350 centimeters as well. When using a thicker blanket, the system is not reliable. A range of about 200 centimeters will probably be enough for this system to work. In most cases, the mobile device can be placed within 2 meters of the sensor. We, as designers of this product, should advise people how to use the product and mention the range of the sensor on the packaging. Also, the limits of the product should be mentioned, such as that it cannot be used with a specific blanket.

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5 INFORMAL TRIAL

Next to a technical evaluation, also an informal trial is currently running with one child coping with nocturnal enuresis and his parents to test comfort and gain insight in the first experiences of using the system. Feedback was gathered through the parents. The first impressions are that after a first night of familiarization, the child does not bother wearing the sensor. The sensor does not seem to affect the comfort of the child and due to the adhesive layer, the sensor remained attached to the underwear/pajama pants throughout the whole night.

However, data about the actual behavior change could not yet be measured since the system is not completely developed yet.

6 CONCLUSION

The concept shows great potential to be a simpler, cheaper and more child-friendly solution to bedwetting. The simple communication method used in the DryNights concept has been successfully evaluated. However, a larger user study will have to be conducted in order to find significant results. Also, the first user impressions are positive. The sensor does not seem to affect the user comfort. However, data about behavior change could not yet be collected.

Future steps in this project are manufacturing a few hundred of these sensors so a user study with about 100 participants can be conducted to evaluate reliability of the sensor. Until now, only the sound-detection algorithm is implemented in the app, in the future the other features also have to be implemented in order to evaluate the overall concept with users.