TangToys: Smart Toys to Communicate and Improve Children's Wellbeing

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ABSTRACT

Children can find it challenging to communicate their emotions especially when experiencing mental health challenges. Technological solutions may help children communicate digitally and receive support from one another as advances in networking and sensors enable the real-time transmission of physical interactions. In this work, we pursue the design of multiple tangible user interfaces designed for children containing multiple sensors and feedback actuators. Bluetooth is used to provide communication between Tangible Toys (TangToys) enabling peer to peer support groups to be developed and allowing feedback to be issued whenever other children are nearby. TangToys can provide a non-intrusive means for children to communicate their wellbeing through play.

CCS CONCEPTS

• **Human-centered computing → Ubiquitous and mobile computing systems and tools**.

KEYWORDS

Tangible User Interfaces; Children; Communication; Mental Wellbeing; Emotion; Sensors

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1 INTRODUCTION

The mental wellbeing of children is increasingly important as more young people than ever before are experiencing high levels of stress [2]. Tangible User Interfaces (TUIs) present new opportunities to digitise physical interfaces to help children communicate their wellbeing. Recent advances in microcontrollers and sensors enable small interfaces to be developed that can process and communicate sensor data in real-time. Children's toys represent an ideal embodiment for TUIs as they provide sufficient space for the electronics and encourage tactile interactions. Although a limited number of TUIs for mental wellbeing have previously been developed, many of these were not engaging for children and often contained physiological sensors which prevent physical interactions commonly used by children to interact with objects such as toys.

While there are many challenges in developing mental wellbeing interfaces, the decreasing cost and increasing capability of networking, sensors and microcontrollers is enabling new forms of interfaces to be developed [16]. An interface that can actively monitor and enable the communication of a user's physical interactions and mood would be beneficial for all. Through the use of Bluetooth Low Energy (BLE), TUIs can communicate with one another enabling real-time communication networks to be developed.

TUIs have previously been used to provide a method to communicate emotions and mental health states [17]. Emoball [5] is a physical ball that enabled users to report their emotions by squeezing the device. Similarly, Subtle Stone [4] allowed users to express their emotions as a colour on the stone. Using colours to represent emotions enabled the private communication of emotions to only those who understood such colour representations. Mood TUI [13] also enabled users to self report their emotions but additionally collected data from the users' smartphones such as location and heart rate. Overall, participants in this study found TUIs exciting to use, and that a small sized device was key for sustained interactions.

The vast majority of previously developed wellbeing interfaces have utilised self-reporting, which children in particular may find challenging. Recent developments in non-invasive sensors introduce the possibility to objectively and intuitively measure physical interactions and physiological changes in real-time. Motion data has previously been used to infer emotions with 81.2% accuracy across 3 classes [19]. However, similar studies reported lower levels of accuracy between 50% - 75% [11] [9] when inferring emotions from motion data.

The ability for children to communicate their emotions is vital as children with difficulties communicating are more at risk in terms of social acceptance and bullying [8]. Furthermore, better relationships and communication with friends offers protection

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against poor mental health in the future [7]. This research introduces Tangible Toys (TangToys) with the aim of communicating mental wellbeing inferred from the embedded sensors. Initial prototypes embed sensors used to measure interactions and well-being and BLE to enable real-time communication. The ability for devices to communicate with one another enables friends to communicate when socially distant and the ability to discover other nearby users. Furthermore, this work highlights key directions for the continued refinement of TangToys.

2 TANGIBLE TOYS (TANGTOYS)

Few sensor based interfaces have been designed for children even though children traditionally find it challenging to communicate their mental wellbeing [10]. We introduce the concept of TangToys as children's toys that embed electronics to measure tangible interactions. The interfaces can vary in shape, size and material including soft balls and teddies designed for younger children aged 5-7 as this is when children develop self-conscious emotions and develop an emotional front [12]. Additionally, 3D printed fidgeting cubes have been designed for older children aged 7-10 as children this age are still developing their emotional awareness [12]. As children physically interact with TangToys in the same way as traditional toys all of the interfaces are suitable for children and encourage engagement by resembling similar toys.

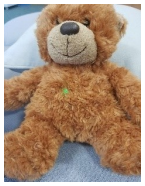
2.1 Communication Framework

Embedding sensors within toys that can communicate with one another through BLE offers many new opportunities for real-time interactions. BLE 4.2 has a range of around 50m allowing TangToys to communicate with one another in locations such as playgrounds. In the following sections we present two opportunities for real-time digital social interaction between TangToys.

Table 1 shows the five TangToys developed during a co-design and co-creation workshop including 2 soft teddies, a soft ball, a 3D printed cube and a 3D printed torus. Each TangToy includes a microcontroller and micro SD card to record all interactions along with BLE 4.2 for communication. A range of sensors can be used to monitor children's interactions with the toys including capacitive sensors to measure touch and 9-Degree Of Freedom Inertial Measurement Unit (9-DOF IMU) to measure motion. Physiological sensors can also be embedded within the toys such as Heart Rate (HR) sensors as they directly correlated with the sympathetic nervous system helping to monitor mental wellbeing [14] [1]. All of the TangToys measure motion and touch interactions while only the 3D printed interfaces designed for older children include physiological sensors, as younger children may not understand the need to place their finger on the physiological sensor whilst playing with the toy.

In addition to the sensors, TangToys can provide real-time interventional feedback [18] activated by wireless communication with other TangToys. Haptic feedback has been included within some of the developed prototypes issuing a physical sense, resembling touch and providing comfort which can improve mental wellbeing [6], [3]. Additionally, visual feedback in the form of multi-coloured LEDs has been included within the soft ball and teddy prototypes.

Table 1: Initial TangToys prototypes.

Device	Image	Description
Ball		A soft ball embedding 9-DOF IMU to measure motion, capacitive sensors to measure touch and Multi-coloured LEDs to perform visual feedback.
Cube		A 3D printed cube embedding 9-DOF IMU, capacitive touch, HR, EDA sensors and haptic feedback
Teddy		A soft teddy embedding 9-DOF IMU, capacitive touch sensor and visual feedback
Torus		A 3D printed tours embedding HR, EDA, 9-DOF IMU, capacitive touch sensor and haptic feedback
Teddy		A soft teddy embedding 9-DOF IMU, capacitive touch sensor, haptic and visual feedback

TangToys have been presented in focus groups to teachers of young students with mild to moderate learning disabilities to provide feedback on the design and functionality of the interfaces [15]. Teachers considered the methods used to interact with TangToys suitable for children and believed the way in which children interact with the toys will indicate their wellbeing. Additionally, teachers liked the design of the toys as they appear similar to other toys helping to reduce stigma. Overall, the teachers reported the design, sensors and communication capabilities were all suitable for children and believed TangToys would promote the communication of wellbeing between friends.

2.1.1 Peer to Peer Communication (P2P). By utilising P2P communication it is possible for two connected devices to communicate with one another. This method of communication helps friends who may be nearby but socially distanced to provide physical communication that is not possible with other devices. When a child plays with a TangToy the capacitive sensor and accelerometer data measuring touch and motion can be actuated on the paired interface through the embedded haptic and visual feedback to simulate physical communication. The connected friend can then react to this

communication by interacting with their device allowing friends to wirelessly support one another through physical interactions.

The range of feedback offered differs depending on the interactions with the paired devices. For example, if a child is aggressively shaking their TangToy or touching it harshly this can result in prolonged sharp haptic feedback patterns being played on the paired device and red visual feedback. This enables friends to physically communicate how they are feeling and provide comfort to one another by replying with soft, gentle interactions to provide comfort and a sense of presence, as shown in Figure 1.

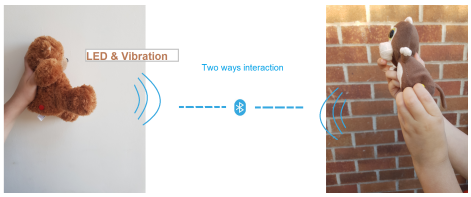


Figure 1: Two children playing using TangToys.

2.1.2 Wireless Scanning. Each TangToy can also use its Bluetooth capabilities to broadcast its presence to other TangToys. When a TangToy detects another device nearby this can initiate feedback being issued to alert the child of other nearby children. This allows a child to find other children who may require support when not near their friends to facilitate peer to peer communication. These children can then interact with the devices to form a support group to communicate their wellbeing to each other. The feedback actuated when detecting other devices can be impacted by the number of nearby interfaces. For example, if a single child is detected nearby more subtle haptic feedback can be issued compared with more pronounced feedback when multiple children are nearby. Similarly, the colour displayed on the TangToy can change dependent on the number of users located nearby to alert the user visually. Using this method of interaction would not enable the same capabilities as the P2P communication, but would enable each device to interact automatically with other nearby devices, and afford a sense of *'togetherness'*.

3 CONCLUSION AND FUTURE WORK

We have presented TangToys, a new concept to combine tangible user interfaces with traditional toys. Various sensors can be embedded within TangToys to communicate physical interactions, such as movement and touch, in real-time with other TangToys. Using a peer to peer communication system enables friends to communicate their wellbeing through device interactions that can then be actuated using haptic and visual feedback on a friend's device. However, there are challenges in distinguishing between emotions that may result in similar interactions. Alternatively, TangToys can simultaneously broadcast and scan for nearby devices allowing for TangToys to discover other TangToys and create local support networks.

In the future, TangToys should be trialled, potentially in schools where children will be able to communicate with each other. The impact of the communication networks can be measured along with the duration in which children use the interfaces. Parental monitoring through the use of a mobile app could also be included, enabling parents to view interactions with the toys.

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