Chapter 24
HeartBit:
Probing Children's Cognitive Skills Using Digital Technology

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ABSTRACT

Biometric heart-rate information is increasingly proliferating through simple wearable technology. However, this technology presents a need for contextual information to guide interpreting physiological responses in lower and higher levels of cognitive abilities. In this paper, the author introduces HeartBit, a sensor-based intervention used for non-obtrusive heart-rate observation of elementary age children within the creative and critical thinking contexts. The author describes the Sandbox as single-session workshop with individual children, the development of HeartBit, and results from Sandboxes with 35 K-1 students (ages 6 and 7). Findings reveal how children's in-situ levels of creativity and critical thinking were observed through an interplay of system design, heart-rate monitoring, and Bloom's Taxonomy educational learning objectives, and how this differed between the individual children.

INTRODUCTION

Observation of children's heart-rate (HR) in relation to their cognitive processes, such as creativity and critical thinking using sensor technology is still in an exploratory stage (Gao, Borlam, & Zhang, 2015). Creativity is often defined as the use of imagination in creating novel ideas, while critical thinking is the self-directive and self-corrective evaluation and analysis of facts (Amabile, 1982). The cognitive domain of Bloom's Taxonomy (e.g. remembering, understanding, applying, analyzing, evaluating, and creating) is used to structure curriculum learning objectives, assessments, and activities (Anderson et al., 2000; Krathwohl, 2002). For adults, electroencephalograms (EEGs) and electrocardiograms (ECGs) are used in laboratory settings to capture the levels of adults' creative cognition (Fink, Schwab, & Papousek, 2011; Mölle, Marshall, Wolf, Fehm, & Born, 1999). However, prior research has shown that

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such assessments are primarily conducted with adults and infants, creating quantitative and statistical results while in controlled environments (Cinaz, Arnrich, La Marca, & Tröster, 2013). This introduces limitations to technology intervention for real-life and uncontrolled evaluation of elementary age children's HR in creativity and critical thinking skills in educational contexts. In addition, recent advances in wearables, such as smartwatches and sensors that are worn in contact with the wearer's body, such as optical HR monitors have enabled collection of data on our physical activities, movement patterns, level of attentiveness, and even boredom (Cinaz et al., 2013; Tan, Schöning, Luyten, & Coninx, 2014).

To address some of the aforementioned issues, we envisioned an educational technology intervention to help educating children about their cognitive abilities while assisting teachers in observing similar parameters. We thus created a high-fidelity prototype (called HeartBit) to explore if changes of the HR in children correlate to the low and high levels of creativity and critical thinking. We designed a study to probe children's HR during both creativity (e.g. drawing) and critical thinking (e.g. circuit making) contexts. We describe our study design process and early insights into the differences in HR, in relation to children's creativity and critical thinking. Our contributions include: (i) findings from Sandboxes characterizing changes in children's HR during the in situ cognitive tasks, and (ii) an analysis of Sandboxes characterizing the differences in children's HR while progressing through lower to higher levels of Bloom's Taxonomy.

BACKGROUND

This review is organized in three parts. The first part reviews sensor-based technology and biofeedback information. The second part provides an overview of physiological changes in relation with cognitive activities. The final part introduces Bloom's Taxonomy.

Biofeedback via Sensors

Alongside skin conductance level, measuring HR is the most common variable used to measure cardiovascular responses to external stimuli (Kreibig, 2010). Typical cuff blood pressure monitors cannot measure changes in pulse in short intervals, but Pulse Transit Time (PTS), which tracks how quickly a blood pressure wave travels from the heart to another point on the body, can be tracked in smaller intervals. Because of this, sensors can be placed on the body and have measurements sent wirelessly to a receiving device, allowing a user to move freely while wearing a device. This also means smaller changes in pulse over time can be tracked, creating a more detailed overview of how levels change over the course of an activity (Tan et al., 2014; Weder, Pietzsch, Zaunseder, Zimmerling, & Netz, 2011). For our study with children, wireless and noninvasive measurements were critical. As these types of wireless sensors become increasingly common in consumer wearables (e.g. smartwatches), they allow researchers to track certain stimuli impact this physiological response in real-time (Merrill & Cheshire, 2017). Prior research has shown that certain emotional stimuli can accelerate and decelerate an HR. Because of the relationship between emotions and biofeedback, researchers can use biofeedback to better track emotional changes. For instance, when an instructor can (unobtrusively) view the biofeedback of a student rather than just monitoring their visible reactions, the instructor can better mediate the activity to lower the stress of the student (or students) (Tan et al., 2014).