Title

1,2,3,4 Tell Me How to Grow More: A Position Paper on Children, Design Ethics and Biowearables

Authors

Alissa N. Antle
School of Interactive Arts and Technology
Simon Fraser University
Surrey, B.C., Canada
aantle@sfu.ca

Alexandra Kitson
School of Interactive Arts and Technology
Simon Fraser University
Surrey, B.C., Canada
akitson@sfu.ca

Abstract

Driven by the rapid pace of technical innovation in biosensing, artificial intelligence, the Internet of Things and wearable computing, the next generation of smart devices will be worn on-body, eventually becoming implanted. The increasing presence of these new forms of interactive technologies, known as *biowearables*, in children's lives poses critical ethical concerns. In this position paper, we take a *design ethics* perspective to identify and describe four cases of ethical importance associated with biowearables, children, and long-term use. The cases concern potential negative impacts of specific aspects of biowearables on children's *identity* formation, the development of *autonomy* and *agency*, and what sources of information children turn to for *authority* about themselves. Drawing on ethical discourse related to emerging technologies and biowearable computing, we present prospective guidance for designers, where it is available. Where guidance is nascent or missing, we propose future research areas that could be addressed. In particular, we propose the importance of teaching children about computer ethics through hands-on critical reflection during design and technology activities. Our results will be of interest to the human-computer interaction community as well as to technology developers, educators, parents and those involved in policy formation around emerging technologies.

1.0 Introduction and Social Importance

The increasing presence of *biowearables* in children's lives poses critical ethical questions for researchers and designers. Ethical discourse related to the parent domains of biowearables is nascent, spread across communities, and largely targets adults. Social scientists, ethicists and technology researchers have scrambled to keep up with the impacts of always connected culture on humans, and little research anticipates this next generation of connected, on-body technologies.

Biowearables' capabilities to sense the wearer's physiological and psychological processes and capture this as biodata are increasing almost as fast as the sales of wearable devices. In some areas of the

developing world, sales of smartwatches far exceed that of other computation devices.[1] Tomorrow's children will grow up connected and also sensed, analyzed and augmented. Their biodata will be commodified; fed into apps that will impact everything from their food intake and footstep count to the formation of their identity, who they turn to for authority about themselves, and perhaps even their very personhood. As biowearables move out of the research lab and into the marketplace it is imperative to explore the ethical and social implications of these emerging technologies.

Much human-computer interaction (HCI) research involves the development of prototypes of emerging technologies that serve as research instruments to study HCI. Research may investigate the impact that interaction has on lived experiences, from productivity and entertainment to identity formation and moral development. What HCI researchers do impacts people—individuals as well as society and as such HCI inherently has ethical dimensions. For example, during HCI research, designers transmit *human values*, either intentionally or not, into the technologies they create [24]. In turn, these influences interact with contextual and societal factors during the use of technologies [59]. Prototyping in HCI research is often mistaken as a precursor to commercialization of products. Instead, as Harrison points out, the greater impact of early stage innovative HCI research is that it explores possibilities, identifies opportunities, and builds a shared vision and talent pipeline [32]. In emerging technology areas, HCI research builds momentum until the technology appears to "burst forth" in industry and the public imagination, looking like the technology had been there all along. In this model of innovation, the window of opportunity for HCI researchers to have impact may be before or early on in the development of commercial products. In designing and studying biowearable technologies researchers are designing new ways of being that set the stage for commercial technologies of tomorrow. In doing so, they are often creating future situations that require ethical consideration now, during the early to mid phase HCI research.

While the quest to create new applications for emerging technology platforms that positively support children's health and well-being seems laudable, the applications, algorithms and technologies that researchers invent, and that operate on users' data, are not neutral. As Friedman suggests, these technologies have a positionality [24]. However, designers and creators of these technologies rarely focus on the values they may express through technology design. Recently there has been a turn in HCI research to examine these values (e.g., [35]). However, without ethical guidance targeted at designers, many of the values that will eventually be embedded in commercial apps will be those of software development companies, whose primary goals are economic. Largely, the goals of all app developers are to capture and capitalize on the end-users' attention. As Harris points out, the best app developers succeed economically because they create a dependency with end-users [32]. If we consider this claim in the emerging area of biowearables, an unsettling picture emerges. Instead of competing for users' screen time–as do Facebook, TikTok, YouTube–this new class of apps competes for users' attention about themselves, and it does so through the collection and commodification of their biodata. Without governance targeted to restrict usage, biodata can be processed to understand, predict and control users' behaviors. What better way to capture a market than to have access to their biodata? In order to avoid normative economic goals driving biowearable development, HCI researchers have a unique opportunity to proactively influence technology development towards economic models of ethical innovation that support human flourishing and well-being rather than business models based on capturing the attention of end-users.

[1] https://www.forbes.com/sites/paullamkin/2018/10/23/smart-wearables-market-to-double-by-2022-27-billion-industry-forecast/#2d92f2f62656

While children's personal data may be protected by governance, e.g., COPPA[2], the impact of processing users' biodata and sending it back to them through apps designed to help them study more effectively, eat better, exercise more and even manage their screen time, is completely unknown. Imagine this scenario we developed based on a conversation with an HCI colleague about her 12-year old son and his smartwatch. A middle school aged child in 2025 is given a biowearable device for Christmas. She installs an app called Healthy Tummy. After a week of monitoring her blood, it has analyzed her gut biome and begins to present information to her about what she should eat to improve her overall health, immune system and emotional state. As she uses the app, she begins to wonder, what does it say about me if I don't make these changes? How am I impacting millions of living creatures every time I eat? Who am I if I consist of a massive biome of creatures? What will happen if I don't follow the app's advice? What if as I age I become depressed like my father, or have memory loss from dementia like my grandmother? Her anxiety level begins to rise, and the app registers this, urging her to increase her daily mindfulness exercises. In response to stress and the desire for control, she begins to limit her food intake. She is ten years old and will spend a lifetime battling anorexia nervosa. Of course, this is an extreme scenario, but fictional scenarios can reveal unanticipated consequences of biowearables designed to improve well-being.

While design ethics issues that have been raised about other interactive technologies for children, including concerns about privacy, consent, confidentiality and security, all apply here, the biosensing capabilities of biowearables raises new issues as well as necessitating new takes on existing issues. Part of these unique concerns arises from values and normative assumptions that may be implicit in the model used to design biowearable applications, which when used by children over time may have negative or unforeseen impacts on their lives and their development into adults. Biowearables that record, track and advise on biological processes and states may impact developing children and youth in a variety of ways. In particular, ongoing monitoring, assessment and feedback will likely reinforce the values and assumptions embedded in applications, with potential adverse effects on the development of children depending on what those values and assumptions are. For example, models based on normative assumptions around productivity and optimization of health may value adherence to pre-set targets (e.g., low heart-rate, high step-count) and the attainment of achievement-based goals (e.g., productive training, minimal stress), which may or may not be appropriate for any particular child. A challenge of research in design ethics and an emerging technology, such as biowearables, is that there are few studies of actual use, therefore most negative impacts must be deduced from available evidence, extended to future use scenarios – an approach we take here. However, our work is also grounded in what is known about factors that may lead to negative impacts on children and youth.

We propose that the motivations of economics combined with the lack of governance, the unexplored possible impacts of normative values, and other ethical issues inherent in biowearables creates an unprecedented, urgent and widespread yet largely invisible societal concern. How may these devices impact end users over time, in particular when those users are children or youth? If we wait until we have clinical or psychological studies that show impact, we put entire generations at risk [78]. As Illes says in her book, *Neuroethics*, it is imperative that we take a future-looking, pragmatic ethical stance on the impact these technologies may have [38].

[2] https://www.ftc.gov/enforcement/rules/rulemaking-regulatory-reform-proceedings/childrens-online-privacy-protection-rule

The need to focus on identifying ethical areas of concern based on potential negative impacts of biowearable use on child development began during the first author's research designing a technology-mediated mental health intervention. A wearable electroencephalogram (EEG) headset[3] was used to create a simple biofeedback system (i.e., brain computer interface (BCI)), which was the focus of an intervention to help young children living in poverty learn and practice self-regulation—details in [3,4]. This research garnered attention from a neuro-ethicist, who invited the first author to a Neuroethics workshop, resulting in a collaboration that focused on identifying ethical issues related to involving children with neurodevelopmental disorders in biomedical research [39]. The first author, now sensitized to child-specific ethical concerns related to technology research, then identified six areas of ethical concern related to biowearables in general. Each area concerned potential adverse impacts that might result from normative assumptions that underlie many of this type of bio-data tracking and monitoring applications and which might have a negative impact on a particular aspect of children's development. In this paper, due to scope, we focus on exploring four areas of ethical concern related to children's developing *identity, autonomy, agency and understanding of authority.* We conceptualize our argument through a lens of individual child development and examine how biowearable design decisions and features might adversely impact individual children who use these devices, in contrast to taking broader lenses such as socio-cultural or socio-economic perspectives. We do not suggest that the four cases we present are definitive or comprise a comprehensive list, but rather that they are a starting point to think deeply about how the kinds of biowearable systems being created may impact children.

To explore this ethical space we posited three research questions: (1) *In what ways do biowearables pose a threat to children's identity, autonomy, agency, and authority*? (2), *What guidance is available to designers around these issues that will help steer the design of biowearables towards a positive agenda focused on children's well-being as they develop? And (3) What research opportunities exist that might identify more areas of potential ethical areas of concern of biowearables on children's lived experiences?*

To begin to address these questions we first present an overview of what is known from the literature related to emerging technologies and ethical issues, focusing on children and biowearables where available, and identifying guidance, where it exists, that may be generalizable to biowearables and children.

2.0 Related Work

2.1 Overview: CCI, Ethics and Well-Being

Ethics in Child-Computer Interaction (CCI) is poorly defined in part due to the interdisciplinary nature of research in this area and a lack of shared theoretical understanding of ethics [12,79]. In a review of the past 18 years of ethics in CCI, researchers found no explicit definition of ethics [79]. One paper divides ethics into procedural ethics versus ethics-in-practice [60]. Procedural ethics seeks institutional approval with an informed consent process. Ethics-in-practice is researchers making judgements and decisions in real-time through careful observation, awareness, and sensitivity. Van Mechelen et al. then go on to describe eight different types of ethics based on their review: formal procedural research ethics, informal procedural research ethics, situational ethics, participation ethics, design ethics, everyday

[3] http://neurosky.com/2017/06/introducing-the-brainlink-pro-an-eeg-headset-for-those-with-mental-wellness-on-their-mind

ethics, teaching design ethics, and teaching everyday ethics. In this paper, we focus on design ethics [79].

Design ethics, or ethics of technology, considers the actual or potential impact of technology on children's well-being. The term "well-being" is also not well defined in the literature. Subjective well-being generally involves life satisfaction, the presence of positive mood, and the absence of negative mood. Researchers have validated several measures of well-being, including neuroimaging, biological markers, and self-report (for a review see [17]). Many factors may impact reports of well-being, including: individual emotions, genes, physical health, environmental and cultural differences. Thus, it is important to consider a multidimensional model of well-being. In terms of designing and developing technology for well-being, Calvo and Peters suggest drawing on different theoretical lenses of well-being and advise researchers to ground projects in existing research and theory or else risk harm [11].

One model of children's well-being was proposed by Amerijckx and Humblet, who suggest that a child's well-being lies at the center of five dimensions: positive-negative, hedonic-eudaimonic, subjective-objective, spiritual-material and collective-individual [1]. Another model of well-being is derived from self-determination theory, and proposes that autonomy, competence, and relatedness needs must be satisfied in order to foster well-being and human flourishing [66]. A third model that is more practice-based includes a range of characteristics that contribute to well-being and healthy psychological development including developing: the ability to self-regulate, feelings of connectedness, resilience against anxiety and depression, a sense of positive self-worth and confidence, and skills that contribute to positive emotions, stability, and perceived safety[4]. In our paper, we take this broadest of perspective on what constitutes well-being through healthy development to consider a range of values, needs, cultural norms and individual factors.

Design ethics raises critical awareness about the actual and potential impact of technology on children's lives and society at large. According to Van Mechelen et al., only 8% of IDC papers address design ethics and teaching children about these issues is an explicit learning goal in only 1% of papers [79]. Therefore, there is a need for addressing design ethics as an overall concern in CCI. Even within design ethics, there are many topics. In this paper, we focus on four ethical areas of concern regarding ways that biowearable technology could negatively impact children as they develop their sense of identity, autonomy, agency and sources of authority about themselves.

Next, we summarize data-centric ethical issues related to biowearables. We then summarize ethical issues from a perspective of design ethics focusing on emerging technologies in general, which is then followed by a section on design ethics in specific contexts. These sections are largely related to issues with adults since there is so little literature related to children, however, we provide this work to orient the reader to the larger dialogue. Lastly, we present the nascent literature on design ethics, biowearables and children.

2.2 Data-Centric Ethical Issues and Biowearables

Much of the conversation on the ethics of biowearables has been data centric–how data is handled, secured, owned, and processed. Most biowearable systems come as black boxes that make it difficult to access data and see how it was processed [77]. That restricted access might mean that users have little

[4] https://www.childhealthindicatorsbc.ca/overview/dimensions-health-well-being

to no access to verifiable evidence of their physiological data. When the reliability of the data is uncertain and with no understanding of how the system works, there is little trust in the system [46,50]. For example, several sleep trackers claim that quantified data is somehow superior to qualitative impressions, when in reality both are prone to error [16]. There is a bias towards thinking the quantified self is somehow more accurate than self-reports.

In terms of data privacy and security, several papers have highlighted the danger of physiological data acting as a biometric "fingerprint" of individuals that could be used in negative ways such as advertisements, medical diagnoses, and job hiring [10]. In seniors, there is concern about identity theft from physiological data [15]. Technologies that used to be thought of as anonymized, such as brain imaging data and movement, we can now decode with Machine Learning algorithms [51,55]. Therefore, there is the potential to use identifiable physiological data in a harmful way; especially for children this has implications for policy, e.g., COPPA, and responsible research.

The data centric focus on biowearable ethics has been largely covered above–for reviews see [13,77]. What has been more neglected in the literature is the potential impact of biowearable technology on the self – that is design ethics, which is the focus of our exploration. In the following subsection, we more broadly review the available work on design ethics and emerging technologies, and then briefly discuss what little research is specifically done with children.

2.3 Design Ethics and Emerging Technologies

In our literature review, we searched for papers with the keywords "ethics AND wearable OR tracking OR smart devices OR technology AND child OR adolescent OR teen" in the ACM (Association for Computing Machinery), IEEE (Institute of Electrical and Electronics Engineers), and the Web of Science databases. We used Google Scholar to identify more articles through backwards references searching.

2.3.1 General Ethical Issues – Adult

Researchers who have conducted recent reviews of ethical issues in digital technology, including personal monitoring devices, have identified that these technologies could potentially impact a person's sense of identity, including the concept of who they are, their moral and social beliefs, and how they relate to others [8,52,53]. Furthermore, these same researchers have identified that these technologies could also create psychological and neurological changes in terms of neuroplasticity, current emotional state, and behaviour. Autonomy is another important topic of ethical consideration, with discussions spanning across disciplines such as psychology, philosophy, public health, and design studies [8]. Autonomy, the freedom to make choices without influence, is often discussed in terms of assistive technologies, smart homes, and health care [52]. Although several articles point to the importance of autonomy as an ethical consideration, it is rarely elaborated on [53]. These reviews found that the ethical considerations of digital technologies touched on issues relating to autonomy, agency and authority. In a review paper, Burr et al. [8] describe a five dimensional model of autonomy by Rughiniş et al. [65] that includes: (1) the user's degree of control and involvement, (2) degree of personalization, (3) degree of truthfulness and reliability, (4) self-understanding regarding goal-pursuit and whether the technology promotes or hinders their own agency, and (5) whether the technology promotes moral deliberation or values in the actions it recommends. Moreover, Mittelstadt [52,53] describes how digital technologies can impact moral and social beliefs people embrace by being obtrusive, e.g., a wearable device becomes an extension of an illness or physical activity that is monitored–I'm a bad sleeper.

We found that the most prominently discussed ethical issue was that despite good intentions, biowearables can be harmful and this is often because of normality assumptions. For example, biowearables are often designed from the perspective of an affluent, active, adult male, which may not be applicable to many other users [7,16,26,58]. There exist inherent values embedded within biowearable devices and systems that are too often overlooked and, unfortunately, can provide sources of information to the wearer that may be false and potentially harmful to their well-being [6,26,35,70,82]. Researchers have also pointed out the potential for biowearables to appear more accurate than they really are, supporting the belief that numbers are superior to qualitative impressions and that the biowearable may know you better than yourself [16,35]. There is little transparency of what these technologies can do and know about a person's emotional state, behaviour, and general well-being [50].

Another prominent ethical issue raised by researchers is that the use of numbers in the quantification of self movement can remove important context, understanding, and reflection on a person's current state and well-being [6,26,58]. These same researchers argue that with limited choices and advice that the biowearable gives out, the less genuine autonomy and choice the wearer has to make their own decisions and act in their best interests. In this context, autonomy means the ability to make self-directed choices without outside influences. Agency means the ability to control, impact, and influence events and the environment without outside influence. Designers and developers of these technologies have the ability to manipulate how people feel about themselves and act, essentially controlling people, which could be in a malicious way, whether that is ill intended or not [6].

One other notable ethical issue that researchers have raised is that when people are asked to compare or judge themselves against some standard or others (e.g., peers), then they could be setting themselves up for disappointment, and see themselves as weak, a failure, or inadequate [26,35,47]. These issues point to the potential for biowearables to change a person's identity in a negative way that may impact their well-being according to Self-determination Theory [66].

2.3.2 Context Specific Ethical Issues – Adult

So far, we have discussed literature focused under ethics and biowearables for adults in a general sense. Next, we describe ethical issues in the context of more specific biowearable devices including virtual and augmented reality (that can track movement, eye-gaze, and other biodata) and physiological sensors, as well as specific contexts such as in the workplace. Although this is not an exhaustive review, it does provide a few examples of potential ethical issues surrounding biowearable devices.

In Bye et al.'s [10] XR Ethical Manifesto, they argue that technologies such as virtual and augmented reality (termed XR) can modulate one's perception because of the strong sense of presence of being in an alternate reality, therefore potentially altering perception of self-identity and relationship to others. They warn that XR can consume our attention and create dependencies through addictive design. XR also has the capacity to use biofeedback and implicit input to undermine agency and autonomy. A review on the ethical issues of smart-glasses, which are like XR but are 2D instead of 3D, found that smart-glasses can change the conceptualization of self as well as agency, dignity, and authenticity because they overlay ordinary reality and colour our ordinary perception of the world [34].

In a study with a biowearable device that detects skin conductance, the authors noted that these devices have the potential to influence how we relate to our own biodata [68]. For example, a device

that says you are stressed, angry, or need to be more active without having the context of what you are doing could be falsely giving you information about yourself.

Wearable robots, which augment human motor functions, have the capacity to impact one's bodily and self-perception because of their intimate connection to the human body [42]. Moreover, the addition of the wearable in augmenting a person's physical form could take away personal responsibility for their actions and choice of movement.

Brain-computer interfaces (BCI) can give you feedback on your brain activity, which can directly or indirectly alter a person's perception of self, tell them how they are feeling, or what actions or behaviours they should take [73]. The potential harm in this being the BCI or interpretation of brain activity could manipulate a person into having a negative identity or taking beliefs or actions that are detrimental to their well-being. For example, people have biases about emotion based on gender or age and these normative assumptions could be embedded in BCI technology that reinforces stereotypes.

In the context of the workplace, Heikkilä et al. [33] found that monitoring or tracking devices gave employees the sense that they were being told what to do, and so their ability to make their own choices and behave normally were hindered. The authors also found employees questioned the feedback of the biowearables as a source of information about themselves, and worried whether this would reflect badly on their perceived work performance.

2.3.3 General Ethical Issues – Children

Though researchers have discussed potential ethical implications of biowearables in the context of adults, there is relatively scarce discussion in the context of children and youth [79]. One of the issues that has been brought up is around norms of physical activity and body targets that can pose a risk to children whose bodies are still growing and maturing [28,29]. For example, biowearable devices that give feedback based on adult bodies may suggest a young person to eat less when in fact they should be eating more to fuel their growing bodies; this could lead the young person to form a warped view of their body and could potentially lead to disordered eating behaviours. Another potential issue is that sharing physiological data, for example on a social network, could lead to bullying, harassment, and lowered self-esteem and well-being [28]. Finally, Goodyear et al. [29] argue that the lack of child or adolescent specific biowearable devices reduces both the autonomy and agency young people have to examine and manage their subjective feelings about their health and their bodies.

2.3.4 Context Specific Ethical Issues – Children

Relatively few researchers have pointed out ethical issues that relate to specific technologies, including robots, virtual reality, self-tracking devices, and smartwatches. There also seems to be some focus on children's learning disabilities, such as ADHD.

Grammenos proposes a thought experiment where a robot develops with a child since birth with adaptable form and evolving capabilities to raise ethical questions around the long term impact of 'always-ON' technologies with children [30]. Similarly, Radu & Antle [63] conducted a thought experiment to explore potential ethical issues raised by a fictional EmbodySuit–a system designed to support children to develop empathy for living creatures in which students experience what it is like to be other living creatures by inhabiting a nano-robot that goes inside real-life natural environments. One of the ethical questions raised was are there negative psychological effects when children embody living

creatures? In the context of VR use with children, Southgate et al. [72] argue that children have a reduced capacity to apply the same cognitive strategies as adults to regulate their experiences and a child's self-concept is still in development. Therefore, these researchers suggest that children are more prone to be influenced by the virtual interactions and experiences of VR; this could result in the child thinking the VR experience actually took place (false memory) or shifting their sense of self.

In studies on self-tracking technology with youth, researchers found that self-tracking can form various identities for the users but this is often not designed around the specific concerns and motives of youth [61,62]. In these same studies, the results suggest that the lack of biowearable devices for youth can potentially create false identities if they are designed with an adult user in mind, who had different life concerns and routines. In a different study with smartwatches and youth, researchers found that smartwatches over long-term use can have negative motivational consequences because of the competitiveness and internal pressure to meet certain normative fitness goals [44]. The authors also found that peer influence through digital technologies may play a negative role in physical activity promotion since young people rely on their peers and other external sources of information about themselves when forming their own values and identity during development. Similarly, children with ADHD have unique challenges that do not fit with designing with normative assumptions [14].

We can see that there are a fair number of ethical considerations around the use of biowearable devices, yet the majority of research has focused on adults. There is not much research on the design ethics of biowearables for children and youth, and we cannot assume that the same issues identified with adults apply to young people because they have reduced capacities compared to adults in many areas (e.g., critical reflection, moral reasoning) and are still forming psychologically and physically. That said, there may be ethical concerns and guidance that do apply across life-spans. Child-specific research and guidance into biowearable design ethics is needed. We begin to address this need with four cases in which biowearable use could negatively impact children's healthy psychological development and well-being.

3.0 Design Ethics, Biowearables and Children: Four Cases

In this section, we present four cases of ethical concern regarding potential negative impacts of biowearables on a child's development. The cases concern: *identity* formation, the development of *autonomy,* the development of a child's sense of *agency*, and what sources of information a child turns to for *authority* about themselves. For each case, we begin with a simple introduction to the developmental construct (i.e., identity, authority, agency, authority) for the purposes of our case study. We explain what it is, how it unfolds during development and why it matters for a child's well-being. Defining each construct precisely is not possible because even the term *development* has many meanings [57], and each developmental construct in turn has a rich and varied theoretical foundation, however we point to key sources for each construct. Next, we present any existing research relating the construct to ethical issues in biowearables, if it exists. We follow this research summary with a discussion of some of the possible ways that children's development for this construct might be negatively impacted by biowearable. We illustrate these possibilities using fictional, speculative scenarios. We created these scenarios based on our own experiences grounded in the available literature. The devices we mention in the scenarios cover a range of devices from those with large consumer uptake, such as kids' fitness trackers[5], kids'

[5] https://www.goodhousekeeping.com/uk/product-reviews/tech/g32486245/kids-fitness-tracker-reviews/

smartwatches[6] and smartphone activity[7] and nutrition apps[8] to emerging technologies, such as stick on or permanent on-skin electrodermal tattoos that are beginning to be used in health applications to monitor glucose levels (and infer daily calorie in-take), stress hormone levels and other blood-based metrics[9]. For each scenario, we stress that much about the design of any particular biowearable application mediates the impact. Lastly, for each of the four cases we present any available guidance that might be used by those involved in research, design, development, education and policy formation around children's biowearables to mediate negative impacts. Note that we refer to each area of ethical area of concern by the name of the theoretical construct in order to anchor our analysis in child development.

3.1 Case 1: Identity

The developmental construct of *Identity* refers to a child's developing sense of who they are [20]. From a child's perspective, identity is their complex and dynamic response to, "Who am I?". Identity formation strongly impacts self-esteem, competence and self-efficacy, which in turn are critical factors impacting well-being [36]. Personal or self identity includes a child's beliefs, thoughts and values about themself; for example, what they think they like and dislike, what they believe their talents and capabilities are and what is important to them (values including moral values) [71]. Identity also concerns how a child thinks others see them [80]. A child may also hold or develop an ideal identity or who they wish to become as a person, which is part of their identity because it reflects how they want to see themselves [20,71].

As a child ages, aspects of identity continuously unfold. As they enter the middle school years and puberty their identity may rapidly shift and change as they may become more self-conscious and self-esteem can drop to an all time low [71]. At this stage, identity is heavily influenced by others, which is why peers are increasingly important through the early teen years [80]. As such, children's identities may be particularly vulnerable to outside influences during these years.

Research has shown that identity formation is also impacted by a child's relationship to tools (e.g., glasses, inhalers and biowearables are just another tool) [37]. As a result, there is potential for continued use of a biowearable to positively or negatively impact how a child forms and thinks about their identity. Biowearable devices that quantify a child's biological processes in real time will impact children throughout their childhood as they formulate their *identity* or sense of self and come to understand who they are as well as who they want to be [39]. Positive identity development happens when the device causes alterations in a child's identity formation which is in line with how they see themselves, or who they want to become [45].

Biowearables may have negative impacts as illustrated by these two speculative scenarios. In the first scenario a smartwatch provides continual feedback that a child has an elevated stress level. Such a scenario would have been likely during various stages of Covid-19. Through daily reminders of a high stress level, it is possible a child could develop an identity that influences the self-concept as a "stressed out" person. This type of negative identity labeling may reinforce rather than mediate negative thoughts and behaviors associated with poor stress regulation resulting in long term deleterious effects. In a second scenario, a smartwatch or fitness tracker could be set up by a parent to help a child monitor

[6] https://www.familyvacationcritic.com/best-smartwatches-for-kids

[7] https://www.activekids.com/parenting-and-family/articles/the-best-fitness-apps-for-kids

[8] https://www.bigcitymoms.com/parenting-articles/8-mobile-apps-to-track-your-childs-nutrition/

[9] https://medicalfuturist.com/digital-tattoos-make-healthcare-more-invisible/

their physical activity level. Children's need for sleep, exercise and caloric intake vary as they grow and go through growth spurts and/or hormonal changes. Many children are not aware of the changing needs of their bodies as they develop. If a child's tracker tells them throughout each day – based on physiological norms for their age group and/or targets set by their caregivers – that they are not exercising enough and they are perhaps eating too much, it may also negatively impact the development of their self-esteem and sense of competency as they fail to meet targets based on norms or set by others. With many fitness trackers it is possible to "cheat" to artificially increase activity level by waving one's arms. So it is not difficult to imagine that a child might decide to cheat to meet targets, particularly if a caregiver has access to that child's progress. As such, long term impacts of using tracking and monitoring applications on identity formation may be a decline in well-being through reduced self-concept and self-esteem.

3.1.1 Ethical Guidance

Although the ethical issue of identity for children or youth using biowearables long-term is mentioned by several researchers [30,44,63], they do not offer any guidance for how we should address this issue. However, we did find one paper that suggests the most effective designs for personal informatics systems for youth should be supportive of youth identity and provide youth with a sense that what they are tracking is consistent with what they know and who they aspire to be [61].

There are also some guidelines for managing ethical issues related to identity for adults, which may also be applicable to children and youth whose identities are at a critical development period. Bye et al. [10] suggest designing experiences across a wide spectrum of physical conditions and/or mental diversity for more inclusive design. The same could be applied to children. For example, Cibrian et al. [14] talk about the unique challenges of children with ADHD and the need for design that caters to a spectrum of neurodiversity. The need for diversity of feedback and expression put forth by Bye et al. is supported by research with children and adolescents, which found that most biowearables are designed for adults and do not adhere to children's specific needs [28,29,44,61,62]. Burr et al. [8] recommend a personalized approach to the design of digital technologies that aim to support well-being since the well-being of an adult is different from a person with dementia, which is also different from that of a healthy and developing child.

3.2 Case 2: *Autonomy*

The developmental construct of *Autonomy* refers to a child's developing competence to make self-directed choices in their life without being strongly influenced by others. From a child's perspective, a child feels autonomous when they are supported and given freedom to ask themselves, "What do I decide?" Autonomous choices may be about the activities they participate in or how they choose to interact with their peers. Autonomy also refers to a child's freedom to set their own goals and objectives [67]. Based on self-determination theory [66] the development of autonomy can be conceptualized to highlight the importance of supporting the development of autonomous motivation [65], a combination of intrinsic motivation, integrated regulation (undertaking an activity through choice to obtain a personal goal), and identified regulation (when the outcome of the behavior is valued) [44].

The development of a strong sense of autonomy strongly impacts a child's sense of themself as secure and confident rather than insecure and full of self-doubt [20,71]. A child who successfully develops skills associated with making autonomous decisions feels capable, tunes into intrinsic motivations and is able

to think critically about their behaviors and communicate with others to do the same. A child who does not acquire these skills is likely left with a sense of guilt, self-doubt, and/or lack of initiative [43]. To support healthy development a child must be given age-appropriate choices, have their opinions respected and be given responsibility.

As a child ages from preschool through the teen years, they learn to assert their power and control over the world through age-appropriate play and increasing, social interactions and well as choices there are enabled to make in their everyday lives. Opportunities to practice independence through decision-making about a range of behaviors, choices and preferences helps them create a sense of mastery over their body, mind and world[10]. Healthy development requires that they be enabled to make decisions and have feedback about their decisions through consequences of their decisions and through feedback from others.

Research has shown that when on-body technologies result in significant behaviour change—for example if they play a causal role in decision making and resulting actions, they may present challenges to the development of autonomy through undue influence [9]. A normative assumption in many biowearable applications is that these apps "empower" people to improve their mental and physical health [8]. This assumption draws on the value that self-determination is beneficial, and in the case of children, age-appropriate. However, as pointed out by Frauenberger, the way in which a biowearable app is designed, commingled with social practices around use, impacts potential positive and negative ways that it influences children's behavior [21].

Biowearables may have negative impacts as illustrated by these two speculative scenarios. In the first scenario, if an on-skin tattoo monitors glucose, uses an algorithm to infer a child's daily calorie intake, and throughout the day tells them to eat more or eat less, it may impact a child's ability to set their own goals and make healthy food choices as part of their developing sense of autonomy – learning when and what to eat and make independent decisions about food choices. At its worst, this could contribute to the development of eating disorders or food-related anxiety. In a second scenario, taken from [8], a mood tracker may be designed to support a child to manage workload in a classroom based on stress. The application may be designed with a goal to improve a child's focus in a classroom in order to improve their "learning". However, the focus of improvement is what a teacher or parent might prioritize, but not what may be important or intrinsically motivating to a child, such as reduced stress. Being monitored and pressured to meet others' goals through digital feedback may significantly increase such a child's stress, and as a result reduce their developing sense of being competent to decide for themselves and/or develop autonomous motivation.

3.2.1 Ethical Guidance

Guidance derived from a mixed method study with youth, aged 13 to 14, using Fitbits to track and monitor exercise showed decreased autonomous (intrinsic) motivation. The authors suggested that exercise trackers should accommodate personalization of health targets, rather than using pre-set targets, which may improve long term motivation and feelings of autonomy [44]. Goodyear [28] recommends getting informed consent from youth when collecting their biodata, so that they may opt out of being tracked or potentially influenced by feedback that may use their data to direct their choices. Cibrian et al. [14] echo this sentiment by suggesting there be options for children to hide or

[10] https://www.canr.msu.edu/news/the_little_toddler_that_could_autonomy_in_toddlerhood

share their wearable and its data with others in order to enhance their ability to make self-directed choices.

Guidance from literature on adults on autonomy also suggests to include the option to not track or quantify data [10,47,52], and instead design for alternate ways of knowing about one self [33,35]. In particular, Burr et al.'s [8] recommend designing digital technologies for well-being with five dimensions of autonomy in mind: degree of control and involvement, degree of personalization, degree of truthfulness and reliability, user's self-understanding and awareness of agency, promotion of moral deliberation and moral values. These same dimensions of autonomy might also be applied to children and youth as a way to empower them by giving them options to self-monitor as well as different ways and perspectives of looking at their own data.

3.3 Case 3: Agency

The developmental construct of *Agency* refers to a child's freedom and developing ability to exert control, impact and have power to influence events and their environment. From a child's perspective, a child develops a sense of agency when they have some control, "What will I do?" Agency refers to a child's freedom to pursue her own goals and take action to meet those goals. Agency is about taking control over actions and behaviors. The importance of a child as an active agent in their own lives is in line with children's rights through the UN Convention on the Rights of the Child [74].

The development of a child's sense of agency through successfully taking action and making an impact in the world supports a child to feel in control and to understand they ways they may influence others and their environment. Opportunities to have agency also contribute to a child's identity through the development of self-esteem and confidence [71]. Conversely, when a child doesn't have agency, either because they cannot take action or their actions fail to have impact, this can lead to low self-esteem, feeling of lack of control and lack of confidence.

Research has shown that as children interact with biowearables through their bio-data, which is quantified, processed and used to make inferences about their biological states, the inaccuracies of this data and it's interpretation present challenges to a child developing feeling of agency, particularly because it is unlikely that they understand the limitations of the device and/or because they may not be able to the objectives set out as targets by the device or others who set those targets for them [28,29].

Biowearables may have negative impacts as illustrated by these two speculative scenarios. In the first scenario, if a child uses a consumer-grade EEG headset and brain training video game to learn to focus their attention, but the data is imprecise and inaccurate relative to their attentive state, the child may develop a sense that they do not have agency. That is, they cannot control their mental state because they cannot control the game. Similarly, if imprecise data is used to generate goals or advice during the game, which may be unattainable, this will surely impact a child's developing sense of agency when they cannot meet their goals [39]. In the second scenario, a child uses an Apple Watch to track their fitness. However, when the data is inaccurate and misses steps or activities, it may not only impact their self-esteem but provide them with evidence that they do not have agency–the ability to positively impact their world, which would negatively impact their developing sense of agency.

3.3.1 ***Ethical Guidance***

The only guidance we could find relating to issues of agency with biowearables for children and youth comes from Goodyear et al. [29] who recommended that adults can help young people better manage their engagement with digital health technologies and ensuring young people have access to feedback where they can critically examine their subjective feelings about their own health and bodies. It also seems likely that helping children and youth understand the limits of these devices would mediate feelings of lack of control when devices do not as anticipated.

There is some guidance on agency that pertains to adults, but might also apply to children and youth. Several papers have mentioned that empowering users to self-monitor can help support the feeling of agency, and that this could be achieved by giving control of feedback or outputs and the rules that govern the input-output mappings over to the users themselves [10,55,70]. It may be possible to do this through educational means. Moreover, we should allow users, perhaps with adult support as mentioned above, to explore their own personal directions and goals without telling them what to do [35,68].

3.4 Case 4: Authority

The developmental construct of *Authority* refers to the sources of information that a child refers to that tells them about themself, in this case about themself, in their daily lives. From a child's perspective, authority refers to the question, "What information do I believe?" These sources may be internal (e.g., how the child is feeling) or external (e.g., what a parent tells them they should be feeling). The development of understanding sources authority strongly impacts what a child takes to be "true" about themselves or others.

Research has shown that technological devices in general may represent sources of authority, in particular to children [22]. Over time, children may to trust or rely on quantified data as a source of authoritative information about themselves, and as a result they may begin to trust and depend on this knowledge about themselves and their peers rather than develop critical thinking skills and/or learn to seek out multiple sources of information about themselves [39]. Again, this issue is attenuated in many cases of biowearables where data or algorithms produce imprecise or inaccurate information, convey information in ways that is not intelligible to children and/or encode biased assumptions about what well-being or productivity look like [27]. In some cases, a technological device presents information to children in ways they do not understand or mis-understand it may cause undue anxiety if they accept it as a valid source of information and do not have skills to assess its validity [28].

Biowearables may have negative impacts as illustrated by these two speculative scenarios. In the first scenario, if a child wears a stress tracking necklace that continually tells them they have a high stress level and urges them to practice relaxation, not only may if impact their developing sense of identity, but it could be confusing or harmful in cases where some stress (high arousal) is beneficial, such as before an exam or sports events. In the second scenario a young teen developing as an athlete may use a smartwatch connected to a training application to try and enhance their strength, endurance and/or motor skills. However, there are many things about a youth's developing body that can't be sensed or considered by the application, in particular as a youth's body grows and changes during puberty. As a result the advice it offers, if followed because it represents a sense of authority, could physically harm a child and undermine their own developing sense learning to be aware of and trust how they are feeling (e.g., tired, hungry, and burned out), which are critical elements to be able to sense for a developing athlete.

3.4.1. Ethical Guidance

Guidance on ethical issues surrounding authority suggests that designers identify the potential risks and harms, then show how their design plans to mitigate risks with the aim to balance risk with opportunity for growth and learning [28]. Young people are often not given a voice in technology development, so some researchers have suggested co-design with children and youth in order to give them some authority over the sources of information about themselves [62]. Similarly, Morrow and Richards [54] recommend that designers use a multimethod strategy that involves participatory methods, including member checking with children and youth so that they feel they have authority over the final product. Southgate et al. [72] recommend taking a human rights view: "How a child is viewed (object, subject, social actor or co-researcher) determines whether the child holds rights in the project and to what extent the child's existing and emerging competencies are valued. . .". When designing technology for children, in this case virtual reality but could be more broadly applied to biowearables in general, the same authors suggest four ethical questions to ask yourself: (1) expertise–do you have research experience with children?; (2) orientation–how are children involved?; (3) design–what are the ethical implications and considerations?; and (4) developmental–what are the potential impacts on children's development? Finally, Goodyear et al. [29] point out that although we make think of biowearables as having 'positive' and 'negative' effects, we must acknowledge that many young people are critical participants of digital technologies who are able to judge for themselves the relevance of information for their age and their bodies, and are capable of navigating inappropriate content.

The guidance derived from the literature focused on adults and biowearables in respect to authority seems to apply to similar guidance for children and youth. First, sensor capabilities should be accurate and transparent in what they can represent and tell the user about themselves [33,50,68,73]. Second, designers must acknowledge assumptions, biases, normative values, and how that can potentially impact the user [8,10,58]. Third, involve users and stakeholders in design [10,42,52]. Fourth, provide space for the user's own reflection and interpretations [33,35,68]. Fifth, focus on moral improvement and self-knowledge rather than physical improvement [26]. Finally, regulate risks through government policy [6,42]. In regards to children and youth, the take-away message here seems to be that rather than telling users about their bodies or instructing them to do specific things, biowearable devices should aim to suggest and provide space for the user's own reflections and interpretations.

3.5 Summary

Taken together, these four areas of concern constitute a starting point for exploring ethical issues that may result from negative or unforeseeable impacts of different forms and designs of biowearables used by children and youth. The guidance we have gleaned from the literature was largely taken from work with adults, and it is likely that both concerns and the need for guidance about ethical consideration to negative impacts are heightened for biowearables to children and youth who are still in formative stages of development.

4.0 Discussion

In this paper we proposed four cases where biowearable use might negatively impact the development of children based on four important constructs in child development. To address our first research question: *In what ways do biowearables pose a threat to children's identity, autonomy, agency, and authority?* we explain each construct and then argue for some of the ways that biowearables might have

negative impacts on a child's development for each construct. We highlight some of these issues using fictional speculative scenarios. These cases serve as exemplars of the kinds of issues that may arise when persuasive, on-body technologies are used by children.

Our argumentation focused on highlighting areas where children may be particularly susceptible to negative impacts for one or more developmental constructs. While these constructs may be similar to those identified in the adult literature, the impacts may be more salient because children may be going through periods of rapid change and/or because their development may be more readily influenced and mediated by digital tools than adults. We suggest that some of these negative impacts during development could have life-long implications on a child's development.

We acknowledge that there may be other developmental constructs worthy of exploration. For example, *personhood*, which can be defined as an individual child's unique set of capabilities and traits based on the particulars of how their brain and body are constituted. Although most biowearables are non-invasive, researchers have questioned the impact they may have on children's neurological development given its plasticity during childhood [75]. If biowearables significantly affect a child's behavior this may result in brain changes, challenging notions of personhood [9]. Another construct of interest is *authenticity*. Authenticity may also be challenged by biowearables that interrupt enjoyment that comes from being present in the moment [32], and if they cause children to experience negative effects when they do not live up to expectations [2].

We address our second research: *What guidance is available to designers around these issues that will help steer the design of biowearables towards a positive agenda focused on children's well-being as they develop?* through our review of the literature, highlighting guidance where available from research with children or from where research with adults that may be applicable. We group and synthesize available guidance across the four cases and present it below as seven areas for consideration.

One key consideration is the importance of personalization, in particular because children develop and self-identify in ways that vary broadly in terms of characteristics and trajectories. Personalization is also important to support a child's developing decision making abilities (through success and failure) around issues related to their own well-being (autonomy) and to take action through related behaviors (agency). Self-determination theory suggests that children develop healthy decision making skills about their well-being when they are supported, at age appropriate levels, to set and monitor their own goals, rather than have them imposed by adults or devices or author sources of authority.

A second key consideration is the importance of transparent and clear communication of information in ways that do not unduly influence children through lack of visibility or force as pointed out by [21]. Communication must be accessible at an age appropriate level to ensure children learn to develop skills in selecting and analyzing sources of information about themselves (authority). In addition, information should be communicated in ways that are not coercive but enables freedom of choice (autonomy), even if those choices may not appear to meet societal norms for well-being, again at age-appropriate levels of risk or harm to the child. Taking care to avoid messaging that may produce anxiety through miscommunication is also critical [31]. Another consideration is information in ways that support children to develop their own sense of authority about themselves, rather than replace it with digitalized information. And as pointed out by [65], what constitutes this type of communicative messages warrants further study, likely both across and between different ages and cultural groups.

The impact of physiological and societal norms leads to a third consideration that impacts guidance. Norms are often assumed, unarticulated and/or based on stereotype users (norms around identity), negating the importance of personalization and the development of autonomous and intrinsic motivation. Another concern raised by Klein et al. is what counts as normal vs abnormal and thus what needs supporting or correcting is often derived from what can be sensed technically [45]. In addition, feminist and disability critiques suggest that prevailing norms around productivity, efficiency and effectiveness carry negative connotations and fail to account for the ways in which environments are inhospitable to variations in individual abilities. A more transparent and nuanced view of the role of norms in biowearable designs (e.g., targets, messages, rewards), an approach in line with value-sensitive design [23], is needed when designing for children's well-being.

A fourth area of importance is guidance that explicates what we mean when we say that a particular biowearable application is empowering children to track and monitor their physical and mental health [8]. A tension exists between empowering children to make age-appropriate autonomous decisions and ensuring they avoid harm and proceed along trajectories of healthy development in terms of their perceptions around self-identity and actions they subsequently take (agency). Guidance from elderly patients (e.g., those with dementia) may apply here since they may have limited capabilities (e.g., see [48] [48]) and warrants exploration for relevancy. We propose an approach to empowerment through involving children in bio-making workshops, described below under future research approaches.

Another consideration that deserves more attention based on discussions in medical ethics, is the role of parents and guardians in determining and influencing children's use and choices during use of biowearables. For example, McDougal and Notini [49] discuss the conflicting guidance concerning decision making around health care decisions involving children where decisions involve ethical issues. They present nine ethical frameworks that explore how conflicts between medical practitioners' recommendations about treatment options and parents' decision making may be resolved. In particular the framework on "best interests" is applicable and brings into question what we mean by the well-being of children and their network of family members.

A sixth relevant area of guidance is to design around alternative ways of knowing as opposed to quantifying biodata as the only way to get information about ourselves [35]. While numbers derived from biodata can have their place in understanding our bodies better, the context of how and when the data were sampled needs to also be considered when interpreting their meaning or else risk misunderstanding or giving unwarranted authority to these data over our internal sense of our well-being. Alternative forms of representing our biodata are needed so that children and adolescents may learn to develop self-regulation skills rather than relying on the narrow, quantified view that devices give about who they are and what to do; these skills are important for well-being and healthy psychological development[11].

Lastly, we also propose children need to better understand the issues they may face. As such, teaching design ethics during technical literacy education is critical as pointed out by several researchers [40,41,76,79]. For issues specific to biowearables, this work may proceed in parallel, but it bequeaths us to conduct more research that investigates what the issues might be, both from our own perspective as

[11] https://www.childhealthindicatorsbc.ca/overview/dimensions-health-well-being

researchers , but also from the perspective of children and youth in order to determine their perspectives on issues and guidance.

To address our third research question: *What research opportunities exist that might identify more areas of potential ethical areas of concern of biowearables on children's lived experiences?* We proposed that future research is needed to explore all the issues discussed here and to reveal other areas of ethical concern. For example, we have yet to explore how biowearables might impact personhood and authenticity (as above) or self-regulation (e.g. addictive device checking). Taking a broader lese than individual child development, there is an opportunity for future research to explore the diversity of trajectories of child development and how it may be influenced by biowearables. Again, using a broader lens, research is needed to consider the breadth of socio-cultural norms and values that are used design biowearables and interpret their outputs. Research, and likely policy and regulation advocacy, is needed to understand how socio-economic factors mediate biowearable design and resulting impacts, as discussed in detail in [6]. For now, we have begun this important dialogue at the level of individual child development using fictional scenarios that are agnostic to age, culture or social norms and do not address economic forces or the need for policy and regulation. It is a start.

In our own recent research work, we are exploring one way to move forward with an investigation that contributes to this ongoing dialogue. While new technologies, such as biowearables, can provide significant benefits to children, realizing these benefits requires the participation of children in both research and co-design of technologies themselves [18,39,81]. We are examining the ethical areas of concern proposed in this paper through a critical making workshop methodology for supporting reflection and eliciting ethical discourse with children during the process of making biowearables. Our is grounded in Nucci's work on the moral development [56] and Ryan and Deci's self-determination theory [66], and informed by practices from VSD technical investigations [25] and critical making [64], all adapted for use with children. Critical making draws on recent work in HCI, including speculative and critical design [19] and reflective design [69]. However, in critical making, participants focus on technological making as constructive processes in which they also engage with scholarly content, such as ethical constructs. The prototypes that result from critical making are considered a means to an end and attain value through the shared act of construction, reflection and discussion. Critical making begins with a set of concepts, which are the four developmental constructs and related ethical issues described in this paper as well as personhood and authenticity. Next, participants are involved in technical and conceptual prototyping over a period of weeks, and explore these concepts through making. Lastly, an iterative process of reconfiguration, discourse and reflection on prototypes offers a means to explore, extend, and critique the original concepts. We have run two online, distributed critical making studies with youth aged 12-14, which are described in [5,83,84]

Taken together, we have identified four potential areas of ethical concern related to negative impacts on biowearables on well-being and child development with nascent guidance that points to related but tangential ethical discourse and suggestions for moving forward into this research space. This work constitutes a small step towards addressing this pressing and growing social issue. We invite you to join the dialogue!

5 Conclusion

Biowearables are not value neutral. How they are designed and how their outputs are interpreted significantly impact how they do or do not contribute to well-being. In this paper we have argued through the lens of individual child development, for some of the ways that biowearables pose a threat to children's well-being as conceptualized as positive development of their identity, autonomy, agency, and authority. Based on ethical guidance available related to biowearables and emerging technologies, both for children and where relevant from work with adults, we have proposed seven considerations for those researching and designing biowearables for children. Consideration of the importance of designing for children as individuals requires support for personalization features, flexibility around use of physiological and society norm used as targets, ways of making data (in)accuracy visible and transparent, and the need for multiple alternative interpretations and representations of biodata that accommodate the needs and situations of individuals. Designers should also be cognizant about what age appropriate empowerment entails, addressing the role of parents and guardians have in helping children understand what biowearables can and cannot tell them about themselves. Lastly, we advocate for children's participation in biowearable design and the need for teaching children about potential negative impacts through design ethics, such as our critical making workshop approach. Taken together consideration of these themes may support researchers to address knowledge gaps and designers to steer the design of biowearables towards a positive agenda focused on children's well-being.

Overall, our work article contributes to ongoing discussions on the design ethics of emerging technologies and design for digital well-being by:

- Identifying and describing four areas of ethical concerns related to key theoretical constructs in children development where biowearable use may negatively impact children;
- Summarizing potential guidance as seven considerations that may be used to address these concerns; and
- Opening up the discussion around new research avenues that may move this ethical discussion forward.

Our work is part of a larger dialogue investigating the philosophical and social implications of recent developments in biowearables in order to open up a dialogue within academia and industry about unique areas of ethical concern that must be considered now as this field emerges.

Acknowledgements

We gratefully acknowledge the support of a NSERC Discovery grant and SFU Innovates grant in funding this nascent work. The first author would also like to acknowledge Dr. Judy Illes for her wonderful early encouragement and ongoing mentorship around exploring ethical issues in technology development for children.

References

[1] Gaëlle Amerijckx and Perrine Claire Humblet. 2014. Child well-being: What does it mean? *Child. Soc.* 28, 5 (2014), 404–415.

[2] Emily Anthes. 2016. Mental health: There's an app for that. *Nature News* 532, 7597 (April 2016), 20–23. DOI:https://doi.org/10.1038/532020a

[3] Alissa N. Antle. 2017. Crazy like us: Design for vulnerable populations. In *Proceedings of the 2017 Conference on Interaction Design and Children* (IDC '17), ACM, New York, NY, USA, 3–4. DOI:https://doi.org/10.1145/3078072.3078074

[4] Alissa N. Antle, Leslie Chesick, Srilekha Kirshnamachari Sridharan, and Emily Cramer. 2018. East meets west: A mobile brain-computer system that helps children living in poverty learn to self-regulate. *Pers. Ubiquitous Comput.* 22, 4 (August 2018), 839–866. DOI:https://doi.org/10.1007/s00779-018-1166-x

[5] Alissa N. Antle, Alexandra Kitson, Yumiko Murai, John Desnoyers-Stewart, Yves Candau, Azadeh Adibi, Katrien Jacobs, and Zoe Dao-Kroeker. 2021. Opportunities and scaffolds for critical reflection on ethical issues in an online after school biowearable workshop for youth. In *Proceedings of the FabLearn Europe 2021 Conference*, ACM New York, NY, USA, Rorschach, Switzerland, (in press, email authors for post-print).

[6] Denise A. Baker. 2020. Four ironies of self-quantification: Wearable technologies and the quantified self. *Sci. Eng. Ethics* 26, 3 (June 2020), 1477–1498. DOI:https://doi.org/10.1007/s11948-020-00181-w

[7] Kirsten Boehner, Shay David, Joseph Kaye, and Phoebe Sengers. 2005. Critical technical practice as a methodology for values in design. In *CHI 2005 Workshop on quality, values, and choices*, 2–7.

[8] Christopher Burr, Mariarosaria Taddeo, and Luciano Floridi. 2020. The ethics of digital well-being: A thematic review. *Sci. Eng. Ethics* 26, 4 (August 2020), 2313–2343. DOI:https://doi.org/10.1007/s11948-020-00175-8

[9] Sasha Burwell, Matthew Sample, and Eric Racine. 2017. Ethical aspects of brain computer interfaces: a scoping review. *BMC Med. Ethics* 18, 1 (November 2017), 60. DOI:https://doi.org/10.1186/s12910-017-0220-y

[10] Kent Bye, Diane Hosfelt, Sam Chase, Matt Miesnieks, and Taylor Beck. 2019. The ethical and privacy implications of mixed reality. In *ACM SIGGRAPH 2019 Panels*, ACM, Los Angeles California, 1–2. DOI:https://doi.org/10.1145/3306212.3328138

[11] Rafael A. Calvo and Dorian Peters. 2014. *Positive Computing: Technology for Well-Being and Human Potential*. The MIT Press. Retrieved from http://www.positivecomputing.org/p/book.html

[12] Jeffrey K.H. Chan. 2018. Design ethics: Reflecting on the ethical dimensions of technology, sustainability, and responsibility in the Anthropocene. *Des. Stud.* 54, (January 2018), 184–200. DOI:https://doi.org/10.1016/j.destud.2017.09.005

[13] Victor Chang, Xin Xu, Barbara Wong, and Victor Mendez. 2019. Ethical problems of smart wearable devices. In *4th International Conference on Complexity, Future Information Systems and Risk*, SciTePress, 121–129.

[14] Franceli L. Cibrian, Kimberley D. Lakes, Arya Tavakoulnia, Kayla Guzman, Sabrina Schuck, and Gillian R. Hayes. 2020. Supporting self-regulation of children with ADHD using wearables: Tensions and design challenges. In *Proceedings of the 2020 CHI Conference on Human Factors in Computing Systems*, ACM, Honolulu HI USA, 1–13. DOI:https://doi.org/10.1145/3313831.3376837

[15] Karen L. Courtney. 2008. Privacy and senior willingness to adopt smart home information technology in residential care facilities. *Methods Inf. Med.* 47, 01 (2008), 76–81. DOI:https://doi.org/10.3414/ME9104

[16] Kate Crawford, Jessa Lingel, and Tero Karppi. 2015. Our metrics, ourselves: A hundred years of self-tracking from the weight scale to the wrist wearable device. *Eur. J. Cult. Stud.* 18, 4–5 (August 2015), 479–496. DOI:https://doi.org/10.1177/1367549415584857
[17] Ed Diener. 2000. Subjective well-being: The science of happiness and a proposal for a national index. *Am. Psychol.* 55, 1 (2000), 34.
[18] Betsy DiSalvo, Jason Yip, Elizabeth Bonsignore, and Carl DiSalvo. 2017. *Participatory Design for Learning: Perspectives from Practice and Research*. Taylor & Francis.
[19] Anthony Dunne and Fiona Raby. 2013. *Speculative Everything: Design, Fiction, and Social Dreaming*. MIT Press.
[20] Erik Homburger Erikson. 1968. Identity youth and crisis, New York (WW Norton) 1968. (1968).
[21] Christopher Frauenberger. 2019. Entanglement HCI the next wave? *ACM Trans. Comput.-Hum. Interact. TOCHI* 27, 1 (2019), 1–27.
[22] Christopher Frauenberger, Alissa N. Antle, Monica Landoni, Janet C. Read, and Jerry Alan Fails. 2018. Ethics in interaction design and children: A panel and community dialogue. In *Proceedings of the 17th ACM Conference on Interaction Design and Children* (IDC '18), ACM, New York, NY, USA, 748–752. DOI:https://doi.org/10.1145/3202185.3210802
[23] Batya Friedman. 1997. *Human Values and the Design of Computer Technology*. Cambridge University Press.
[24] Batya Friedman and David Hendry. 2019. *Value Sensitive Design: Shaping Technology with Moral Imagination*. MIT Press.
[25] Batya Friedman, David G. Hendry, and Alan Borning. 2017. A survey of value sensitive design methods. *Found. Trends® Human–Computer Interact.* 11, 2 (2017), 63–125.
[26] Katleen Gabriels and Mark Coeckelbergh. 2019. 'Technologies of the self and other': how self-tracking technologies also shape the other. *J. Inf. Commun. Ethics Soc.* 17, 2 (May 2019), 119–127. DOI:https://doi.org/10.1108/JICES-12-2018-0094
[27] Urs Gasser and Sandra Cortesi. 2016. Children's rights and digital technologies: Introduction to the discourse and some meta-observations. *Handb. Child. Rights Glob. Multidiscip. Perspect. M Ruck M Peterson-Badali M Freeman Eds Taylor Francis Forthcom.* (2016).
[28] Victoria A. Goodyear. 2017. Social media, apps and wearable technologies: navigating ethical dilemmas and procedures. *Qual. Res. Sport Exerc. Health* 9, 3 (May 2017), 285–302. DOI:https://doi.org/10.1080/2159676X.2017.1303790
[29] Victoria A. Goodyear, Kathleen M. Armour, and Hannah Wood. 2019. Young people learning about health: The role of apps and wearable devices. *Learn. Media Technol.* 44, 2 (2019), 193–210.
[30] Dimitris Grammenos. 2016. roboTwin: A modular & evolvable robotic companion for children. In *Proceedings of the The 15th International Conference on Interaction Design and Children*, ACM, Manchester United Kingdom, 742–744. DOI:https://doi.org/10.1145/2930674.2955210
[31] Jacqueline A. Hall, Rena Gertz, Joan Amato, and Claudia Pagliari. 2017. Transparency of genetic testing services for 'health, wellness and lifestyle': analysis of online prepurchase information for UK consumers. *Eur. J. Hum. Genet.* 25, 8 (August 2017), 908–917. DOI:https://doi.org/10.1038/ejhg.2017.75
[32] Tristan Harris. Tristan Harris | Speaker | TED. Retrieved April 24, 2019 from https://www.ted.com/speakers/tristan_harris
[33] Päivi Heikkilä, Anita Honka, Sebastian Mach, Franziska Schmalfuß, Eija Kaasinen, and Kaisa Väänänen. 2018. Quantified factory worker - Expert evaluation and ethical considerations of wearable self-tracking devices. In *Proceedings of the 22nd International Academic Mindtrek Conference*, ACM, Tampere Finland, 202–211. DOI:https://doi.org/10.1145/3275116.3275119

[34] Bjørn Hofmann, Dušan Haustein, and Laurens Landeweerd. 2017. Smart-glasses: Exposing and elucidating the ethical issues. *Sci. Eng. Ethics* 23, 3 (June 2017), 701–721. DOI:https://doi.org/10.1007/s11948-016-9792-z

[35] Noura Howell, John Chuang, Abigail De Kosnik, Greg Niemeyer, and Kimiko Ryokai. 2018. Emotional biosensing: Exploring critical alternatives. *Proc. ACM Hum.-Comput. Interact.* 2, CSCW (November 2018), 1–25. DOI:https://doi.org/10.1145/3274338

[36] Felicia A. Huppert and Timothy TC So. 2013. Flourishing across Europe: Application of a new conceptual framework for defining well-being. *Soc. Indic. Res.* 110, 3 (2013), 837–861.

[37] Ian Hutchby and Jo Moran-Ellis. 2013. *Children, Technology and Culture: The Impacts of Technologies in Children's Everyday Lives*. Routledge.

[38] Judy Illes. 2017. *Neuroethics: Anticipating the future*. Oxford University Press.

[39] Judy Illes, Alissa N. Antle, Hayami Lou, Holly Longstaff, Vasiliki Rahimzadeh, Patrick J. McDonald, and HF Machiel Van der Loos. 2019. Involving children with neurodevelopmental disorders in biomedical research. *Lancet Child Adolesc. Health* 3, 3 (March 2019), 143–144. DOI:https://doi.org/10.1016/S2352-4642(19)30022-7

[40] Ole Sejer Iversen, Rachel Charlotte Smith, and Christian Dindler. 2018. From computational thinking to computational empowerment: a 21st century PD agenda. In *Proceedings of the 15th Participatory Design Conference: Full Papers-Volume 1*, 1–11.

[41] Yasmin Kafai, Chris Proctor, and Debora Lui. 2019. From theory bias to theory dialogue: Embracing cognitive, situated, and critical framings of computational thinking in k-12 cs education. In *Proceedings of the 2019 ACM Conference on International Computing Education Research*, 101–109.

[42] Alexandra Kapeller, Heike Felzmann, Eduard Fosch-Villaronga, and Ann-Marie Hughes. 2020. A taxonomy of ethical, legal and social implications of wearable robots: An expert perspective. *Sci. Eng. Ethics* 26, 6 (December 2020), 3229–3247. DOI:https://doi.org/10.1007/s11948-020-00268-4

[43] Kendra Cherry. Understanding Erikson's Stages of Psychosocial Development. *Verywell Mind*. Retrieved January 12, 2021 from https://www.verywellmind.com/erik-eriksons-stages-of-psychosocial-development-2795740

[44] Charlotte Kerner and Victoria A. Goodyear. 2017. The motivational impact of wearable healthy lifestyle technologies: A self-determination perspective on Fitbits with adolescents. *Am. J. Health Educ.* 48, 5 (September 2017), 287–297. DOI:https://doi.org/10.1080/19325037.2017.1343161

[45] Eran Klein, Tim Brown, Matthew Sample, Anjali R. Truitt, and Sara Goering. 2015. Engineering the brain: Ethical issues and the introduction of neural devices. *Hastings Cent. Rep.* 45, 6 (November 2015), 26–35. DOI:https://doi.org/10.1002/hast.515

[46] Bran Knowles, Alison Smith-Renner, Forough Poursabzi-Sangdeh, Di Lu, and Halimat Alabi. 2018. Uncertainty in current and future health wearables. *Commun. ACM* 61, 12 (November 2018), 62–67. DOI:https://doi.org/10.1145/3199201

[47] Karola V. Kreitmair, Mildred K. Cho, and David C. Magnus. 2017. Consent and engagement, security, and authentic living using wearable and mobile health technology. *Nat. Biotechnol.* 35, 7 (July 2017), 617–620. DOI:https://doi.org/10.1038/nbt.3887

[48] Isabel Margot-Cattin and Louise Nygård. 2006. Access technology and dementia care: Influences on residents' everyday lives in a secure unit. *Scand. J. Occup. Ther.* 13, 2 (2006), 113–124.

[49] Rosalind J. McDougall and Lauren Notini. 2014. Overriding parents' medical decisions for their children: a systematic review of normative literature. *J. Med. Ethics* 40, 7 (2014), 448–452.

[50] Nick Merrill, John Chuang, and Coye Cheshire. 2019. Sensing is believing: What people think biosensors can reveal about thoughts and feelings. In *Proceedings of the 2019 on Designing Interactive Systems Conference*, ACM, San Diego CA USA, 413–420. DOI:https://doi.org/10.1145/3322276.3322286

[51] Kai J. Miller, Dora Hermes, and Nathan P. Staff. 2020. The current state of electrocorticography-based brain–computer interfaces. *Neurosurg. Focus* 49, 1 (2020), E2.
[52] Brent Mittelstadt. 2017. Ethics of the health-related internet of things: a narrative review. *Ethics Inf. Technol.* 19, 3 (September 2017), 157–175. DOI:https://doi.org/10.1007/s10676-017-9426-4
[53] Brent Mittelstadt, N. Ben Fairweather, Mark Shaw, and Neil McBride. 2011. Ethical issues of personal health monitoring: A literature review. *The Social Impact of Social Computing* 313 (2011).
[54] Virginia Morrow and Martin Richards. 1996. The ethics of social research with children: An overview 1. *Child. Soc.* 10, 2 (1996), 90–105.
[55] Eisuke Nakazawa, Keiichiro Yamamoto, Koji Tachibana, Soichiro Toda, Yoshiyuki Takimoto, and Akira Akabayashi. 2016. Ethics of Decoded Neurofeedback in Clinical Research, Treatment, and Moral Enhancement. *AJOB Neurosci.* 7, 2 (April 2016), 110–117. DOI:https://doi.org/10.1080/21507740.2016.1172134
[56] Larry Nucci, Michael W. Creane, and Deborah W. Powers. 2015. Integrating moral and social development within middle school social studies: A social cognitive domain approach. *J. Moral Educ.* 44, 4 (2015), 479–496.
[57] Willis F. Overton. 2010. Life-span development: Concepts and issues. *Handb. Life-Span Dev.* (2010).
[58] John Owens and Alan Cribb. 2019. 'My Fitbit thinks I can do better!' Do health promoting wearable technologies support personal autonomy? *Philos. Technol.* 32, 1 (March 2019), 23–38. DOI:https://doi.org/10.1007/s13347-017-0266-2
[59] Dorian Peters, Rafael A. Calvo, and Richard M. Ryan. 2018. Designing for motivation, engagement and wellbeing in digital experience. *Front. Psychol.* 9, (2018). DOI:https://doi.org/10.3389/fpsyg.2018.00797
[60] Shanon K. Phelan and Elizabeth Anne Kinsella. 2013. Picture this... safety, dignity, and voice—Ethical research with children: Practical considerations for the reflexive researcher. *Qual. Inq.* 19, 2 (2013), 81–90.
[61] Kyrill Potapov, Victor R. Lee, Asimina Vasalou, and Paul Marshall. 2019. Youth concerns and responses to self-tracking tools and personal informatics systems. In *Extended Abstracts of the 2019 CHI Conference on Human Factors in Computing Systems*, ACM, Glasgow Scotland Uk, 1–6. DOI:https://doi.org/10.1145/3290607.3312886
[62] Kyrill Potapov and Paul Marshall. 2020. LifeMosaic: co-design of a personal informatics tool for youth. In *Proceedings of the Interaction Design and Children Conference* (IDC '20), ACM, New York, NY, USA, 519–531. DOI:https://doi.org/10.1145/3392063.3394429
[63] Iulian Radu and Alissa N. Antle. 2016. All creatures great and small: Becoming other organisms through the EmbodySuit. In *Proceedings of the The 15th International Conference on Interaction Design and Children*, ACM, Manchester United Kingdom, 751–758. DOI:https://doi.org/10.1145/2930674.2955209
[64] Matt Ratto. 2011. Critical making: Conceptual and material studies in technology and social life. *Inf. Soc.* 27, 4 (July 2011), 252–260. DOI:https://doi.org/10.1080/01972243.2011.583819
[65] Cosima Rughiniş, Răzvan Rughiniş, and Ştefania Matei. 2015. A touching app voice thinking about ethics of persuasive technology through an analysis of mobile smoking-cessation apps. *Ethics Inf. Technol.* 17, 4 (2015), 295–309.
[66] Richard M. Ryan and Edward L. Deci. 2000. Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *Am. Psychol.* 55, 1 (2000), 68–78. DOI:https://doi.org/10.1037/0003-066X.55.1.68
[67] Richard M. Ryan and Heather Patrick. 2009. Self-determination theory and physical activity: The dynamics of motivation in development and wellness. *Hell. J. Psychol.* 6, (2009), 107–124.

[68] Pedro Sanches, Kristina Höök, Corina Sas, and Anna Ståhl. 2019. Ambiguity as a resource to inform proto-practices: The case of skin conductance. *ACM Trans. Comput.-Hum. Interact.* 26, 4 (July 2019), 1–32. DOI:https://doi.org/10.1145/3318143

[69] Phoebe Sengers, Kirsten Boehner, Shay David, and Joseph'Jofish' Kaye. 2005. Reflective design. In *Proceedings of the 4th decennial conference on Critical computing: between sense and sensibility*, ACM, 49–58.

[70] Phoebe Sengers, Kirsten Boehner, Simeon Warner, and Tom Jenkins. 2005. Evaluating affector: Co-interpreting what "works." In *CHI 2005 Workshop on Innovative Approaches to Evaluating Affective Interfaces*, 4.

[71] Robert S. Siegler, Judy S. DeLoache, and Nancy Eisenberg. 2003. *How Children Develop*. Macmillan.

[72] Erica Southgate, Shamus P. Smith, and Jill Scevak. 2017. Asking ethical questions in research using immersive virtual and augmented reality technologies with children and youth. In *2017 IEEE Virtual Reality (VR)*, IEEE, Los Angeles, CA, USA, 12–18. DOI:https://doi.org/10.1109/VR.2017.7892226

[73] Steffen Steinert and Orsolya Friedrich. 2020. Wired emotions: Ethical issues of affective brain–computer interfaces. *Sci. Eng. Ethics* 26, 1 (February 2020), 351–367. DOI:https://doi.org/10.1007/s11948-019-00087-2

[74] Ferdinand Sutterlüty and E. Kay M. Tisdall. 2019. Agency, autonomy and self-determination: Questioning key concepts of childhood studies. *Glob. Stud. Child.* 9, 3 (September 2019), 183–187. DOI:https://doi.org/10.1177/2043610619860992

[75] Guglielmo Tamburrini. 2009. Brain to computer communication: Ethical perspectives on interaction models. *Neuroethics* 2, 3 (November 2009), 137–149. DOI:https://doi.org/10.1007/s12152-009-9040-1

[76] Mike Tissenbaum, Josh Sheldon, and Hal Abelson. 2019. From computational thinking to computational action. *Commun. ACM* 62, 3 (2019), 34–36.

[77] Lauri Tuovinen and Alan F. Smeaton. 2019. Unlocking the black box of wearable intelligence: Ethical considerations and social impact. In *2019 IEEE Congress on Evolutionary Computation (CEC)*, IEEE, Wellington, New Zealand, 3235–3243. DOI:https://doi.org/10.1109/CEC.2019.8790173

[78] Ulrich Gasper. 2018. Children at Play: Thoughts about the impact of networked toys in the game of life and the role of law. *The International Review of Information Ethics*. 27 (December 2018).

[79] Maarten Van Mechelen, Gökçe Elif Baykal, Christian Dindler, Eva Eriksson, and Ole Sejer Iversen. 2020. 18 Years of ethics in child-computer interaction research: A systematic literature review. In *Proceedings of the Interaction Design and Children Conference*, ACM, London United Kingdom, 161–183. DOI:https://doi.org/10.1145/3392063.3394407

[80] Lev Semenovich Vygotsky. 1980. *Mind in society: The development of higher psychological processes*. Harvard university press.

[81] Greg Walsh, Elizabeth Foss, Jason Yip, and Allison Druin. 2013. FACIT PD: a framework for analysis and creation of intergenerational techniques for participatory design. In *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, ACM, 2893–2902.

[82] Elizabeth Wissinger. 2017. Wearable tech, bodies, and gender. *Sociol. Compass* 11, 11 (November 2017), e12514. DOI:https://doi.org/10.1111/soc4.12514

[83] Yumiko Murai, Alissa N. Antle, Alexandra Kitson, Azadeh Adibi, Yves Candau, John Desnoyers-Stewart, Katrien Jacobs, and Zoë Dao-Kroeker. 2021. Scaffolding online distributed critical making: lessons learned. In *Proceedings of FabLearn Europe*, Online (in press, email authors for post-print).

[84] Zoë Dao-Kroeker, Alissa N. Antle, Alexandra Kitson, Yumiko Murai, and Azadeh Adibi. 2021. Designing bio-tech ethics cards: Promoting critical making during an online workshop with youth. In *Proceedings of Conference on Interaction Design for Children*, ACM Press New York, NY, USA, Online (in press, email authors for post-print).