

# 1,2,3,4 tell me how to grow more: A position paper on children, design ethics and biowearables

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## A B S T R A C T

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. 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.<sup>1</sup> 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 (Friedman & Hendry, 2019). In turn, these influences interact with contextual and societal factors during the use of technologies (Peters, Calvo, & Ryan, 2018). 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 (Harris, 2019). 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

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

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 (Friedman & Hendry, 2019). 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., Howell, Chuang, De Kosnik, Niemeyer, & Ryokai, 2018). 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 (Harris, 2019). 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.

While children's personal data may be protected by governance, e.g., COPPA,<sup>2</sup> 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 do not 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 do not 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 raise 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 (Gasper, 2018). 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 (Illes, 2017).

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<sup>3</sup> 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 Antle (2017), Antle, Chesick, Sridharan, and Cramer (2018). 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 (Illes et al., 2019). 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

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

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

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. 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 (Chan, 2018; Van Mechelen, Baykal, Christian Dindler, & Iversen, 2020). In a review of the past 18 years of ethics in CCI, researchers found no explicit definition of ethics (Van Mechelen et al., 2020). One paper divides ethics into procedural ethics versus ethics-in-practice (Phelan & Kinsella, 2013). Procedural ethics seeks institutional approval with an informed consent process. Ethics-in-practice is researchers making judgments 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 ethics, teaching design ethics, and teaching everyday ethics. In this paper, we focus on design ethics (Van Mechelen et al., 2020).

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 Diener (2000)). 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 (Calvo & Peters, 2014).

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 (Amerijckx & Humblet, 2014). 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 (Ryan & Deci, 2000). 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.<sup>4</sup> In our paper, we take this broadest of perspectives 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 (Van Mechelen et al., 2020). 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 dialog. 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 (Tuovinen & Smeaton, 2019). That restricted access might mean that users have little 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 (Knowles, Smith-Renner, Poursabzi-Sangdeh, Lu, & Alabi, 2018; Merrill, Chuang, & Cheshire, 2019). For example, several sleep trackers claim that quantified data is somehow superior to qualitative impressions, when in reality both are prone to error (Crawford, Lingel, & Karppi, 2015). 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 (Bye, Hosfelt, Chase, Miesnieks, & Beck, 2019). In seniors, there is concern about identity theft from physiological data (Courtney, 2008). Technologies that used to be thought of as anonymized, such as brain imaging data and movement, we can now decode with Machine Learning algorithms (Miller, Hermes, & Staff, 2020; Nakazawa et al., 2016). 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 Chang, Xu, Wong, and Mendez (2019), Tuovinen and Smeaton (2019). 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.

<sup>4</sup> <https://www.childhealthindicatorsbc.ca/overview/dimensions-health-well-being>.

### 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 (Burr, Taddeo, & Floridi, 2020; Mittelstadt, 2017; Mittelstadt, Ben Fairweather, Shaw, & McBride, 2011). Furthermore, these same researchers have identified that these technologies could also create psychological and neurological changes in terms of neuroplasticity, current emotional state, and behavior. Autonomy is another important topic of ethical consideration, with discussions spanning across disciplines such as psychology, philosophy, public health, and design studies (Burr et al., 2020). Autonomy, the freedom to make choices without influence, is often discussed in terms of assistive technologies, smart homes, and health care (Mittelstadt, 2017). Although several articles point to the importance of autonomy as an ethical consideration, it is rarely elaborated on Mittelstadt et al. (2011). 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. (2020) describe a five dimensional model of autonomy by Rughiniş, Rughiniş, and Matei (2015) 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 (2017), Mittelstadt et al. (2011) 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 (Boehner, David, Kaye, & Sengers, 2005; Crawford et al., 2015; Gabriels & Coeckelbergh, 2019; Owens & Cribb, 2019). 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 (Baker, 2020; Gabriels & Coeckelbergh, 2019; Howell et al., 2018; Sengers, Boehner, Warner, & Jenkins, 2005; Wissinger, 2017). 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 (Crawford et al., 2015; Howell et al., 2018). There is little transparency of what these technologies can do and know about a person’s emotional state, behavior, and general well-being (Merrill et al., 2019).

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 (Baker, 2020; Gabriels & Coeckelbergh, 2019; Owens & Cribb, 2019). 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 (Baker, 2020).

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 (Gabriels & Coeckelbergh, 2019; Howell et al., 2018; Kreitmair, Cho, & Magnus, 2017). 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 (Ryan & Deci, 2000).

#### 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. (2019) 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 color our ordinary perception of the world (Hofmann, Hausteine, & Landeweerd, 2017).

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 (Sanches, Höök, Sas, & Ståhl, 2019). 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 (Kapeller, Felzmann, Fosch-Villaronga, & Hughes, 2020). 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 behaviors they should take (Steinert & Friedrich, 2020). 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. (2018) 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 (Van Mechelen et al., 2020). 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 (Goodyear, 2017; Goodyear, Armour, & Wood, 2019). 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 behaviors. 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 (Goodyear, 2017). Finally, Goodyear et al. (2019) 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 (Grammenos, 2016). Similarly, Radu and Antle (2016) 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, Smith, and Scevak (2017) 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 (Potapov, Lee, Vasalou, & Marshall, 2019; Potapov & Marshall, 2020). 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 (Kerner & Goodyear, 2017). 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 (Cibrian et al., 2020).

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. 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 (Overton, 2010), 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 biowearables. 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,<sup>5</sup> kids' smartwatches<sup>6</sup> and smartphone activity<sup>7</sup> and nutrition apps<sup>8</sup> 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.<sup>9</sup> For each scenario, we stress that much about the design of any particular

<sup>5</sup> <https://www.goodhousekeeping.com/uk/product-reviews/tech/g32486245/kids-fitness-tracker-reviews/>.

<sup>6</sup> <https://www.familyvacationcritic.com/best-smartwatches-for-kids>.

<sup>7</sup> <https://www.activekids.com/parenting-and-family/articles/the-best-fitness-apps-for-kids>.

<sup>8</sup> <https://www.bigcitymoms.com/parenting-articles/8-mobile-apps-to-track-your-childs-nutrition/>.

<sup>9</sup> <https://medicafuturist.com/digital-tattoos-make-healthcare-more-invisible/>.

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 (Erikson, 1968). 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 (Huppert & So, 2013). Personal or self identity includes a child's beliefs, thoughts and values about themselves; 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) (Siegler, DeLoache, & Eisenberg, 2003). Identity also concerns how a child thinks others see them (Vygotsky, 1980). 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 (Erikson, 1968; Siegler et al., 2003).

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 (Siegler et al., 2003). At this stage, identity is heavily influenced by others, which is why peers are increasingly important through the early teen years (Vygotsky, 1980). 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) (Hutchby & Moran-Ellis, 2013). 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 (Illes et al., 2019). 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 (Klein, Brown, Sample, Truitt, & Goering, 2015).

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 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 (Grammenos, 2016; Kerner & Goodyear, 2017; Radu & Antle, 2016), 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 (Potapov et al., 2019).

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. (2019) 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. (2020) 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 (Goodyear, 2017; Goodyear et al., 2019; Kerner & Goodyear, 2017; Potapov et al., 2019; Potapov & Marshall, 2020). Burr et al. (2020) 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 (Ryan & Patrick, 2009). Based on self-determination theory (Ryan & Deci, 2000) the development of autonomy can be conceptualized to highlight the importance of supporting the development of autonomous motivation (Rughiniş et al., 2015), 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) (Kerner & Goodyear, 2017).

The development of a strong sense of autonomy strongly impacts a child's sense of themselves as secure and confident rather than insecure and full of self-doubt (Erikson, 1968; Siegler et al., 2003). 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 (Cherry, 2021). 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.<sup>10</sup> 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 behavior 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 (Burwell, Sample, & Racine, 2017). A normative assumption in many biowearable applications is that these apps “empower” people to improve their mental and physical health (Burr et al., 2020). 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 (Frauenberger, 2019).

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 making 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 Burr et al. (2020), 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 (Kerner & Goodyear, 2017). Goodyear (2017) 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. (2020) echo this sentiment by suggesting there be options for children to hide or share their wearable and its data with others in order to enhance their ability to make self-directed choices.

<sup>10</sup> [https://www.canr.msu.edu/news/the\\_little\\_toddler\\_that\\_could\\_autonomy\\_in\\_toddlerhood](https://www.canr.msu.edu/news/the_little_toddler_that_could_autonomy_in_toddlerhood).

Guidance from literature on adults on autonomy also suggests to include the option to not track or quantify data (Bye et al., 2019; Kreitmair et al., 2017; Mittelstadt, 2017), and instead design for alternate ways of knowing about oneself (Heikkilä et al., 2018; Howell et al., 2018). In particular, Burr et al.’s (2020) 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 (Sutterlüty, Kay, & Tisdall, 2019).

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 (Siegler et al., 2003). Conversely, when a child does not 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 its 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 meet the objectives set out as targets by the device or others who set those targets for them (Goodyear, 2017; Goodyear et al., 2019).

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 (Illes et al., 2019). 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. \(2019\)](#) who recommended that adults can help young people better manage their engagement with digital health technologies and ensure 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 perform 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 ([Bye et al., 2019](#); [Nakazawa et al., 2016](#); [Sengers, Boehner, Warner, et al., 2005](#)). 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 ([Howell et al., 2018](#); [Sanches et al., 2019](#)).

### 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 themselves, in this case about themselves, 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 of authority sources 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 ([Frauenberger, Antle, Landoni, Read, & Fails, 2018](#)). Over time, children may come 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 developing critical thinking skills and/or learning to seek out multiple sources of information about themselves ([Illes et al., 2019](#)). Again, this issue is attenuated in many cases of biowearables where data or algorithms produce imprecise or inaccurate information, convey information in ways that are not intelligible to children and/or encode biased assumptions about what well-being or productivity look like ([Gasser & Cortesi, 2016](#)). In some cases, when 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 ([Goodyear, 2017](#)).

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 it 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 cannot 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 awareness of, and trust in 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 ([Goodyear, 2017](#)). 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 ([Potapov & Marshall, 2020](#)). Similarly, [Morrow and Richards \(1996\)](#) 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. \(2017\)](#) 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 the guidance 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. \(2019\)](#) point out that although we make think of biowearables as having 'positive' and 'negative' effects, we must acknowledge that many young people are critical users 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 ([Heikkilä et al., 2018](#); [Merrill et al., 2019](#); [Sanches et al., 2019](#); [Steinert & Friedrich, 2020](#)). Second, designers must acknowledge assumptions, biases, normative values, and how that can potentially impact the user ([Burr et al., 2020](#); [Bye et al., 2019](#); [Owens & Cribb, 2019](#)). Third, involve users and stakeholders in design ([Bye et al., 2019](#); [Kapeller et al., 2020](#); [Mittelstadt, 2017](#)). Fourth, provide space for the user's own reflection and interpretations ([Heikkilä et al., 2018](#); [Howell et al., 2018](#); [Sanches et al., 2019](#)). Fifth, focus on moral improvement and self-knowledge rather than physical improvement ([Gabriels & Coeckelbergh, 2019](#)). Finally, regulate risks through government policy ([Baker, 2020](#); [Kapeller et al., 2020](#)). 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. 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 (Tamburrini, 2009). If biowearables significantly affect a child's behavior this may result in brain changes, challenging notions of personhood (Burwell et al., 2017). Another construct of interest is *authenticity*. Authenticity may also be challenged by biowearables that interrupt enjoyment that comes from being present in the moment (Harris, 2019), and if they cause children to experience negative effects when they do not live up to expectations (Anthes, 2016).

We address our second research question: *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 Frauenberger (2019). 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 (Hall, Gertz, Amato, & Pagliari, 2017). Another consideration is to provide 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 Rughiniş et al. (2015), what constitutes this type of communicative messaging 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 (Klein et al., 2015). 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 (Friedman, 1997), 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 (Burr et al., 2020). 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 Margot-Cattin and Nygård (2006, 2006)) 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, McDougall and Notini (2014) 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 (Howell et al., 2018). 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.<sup>11</sup>

<sup>11</sup> <https://www.childhealthindicatorsbc.ca/overview/dimensions-health-well-being>.

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 (Iversen, Smith, & Dindler, 2018; Kafai, Proctor, & Lui, 2019; Tissenbaum, Sheldon, & Abelson, 2019; Van Mechelen et al., 2020). For issues specific to biowearables, this work may proceed in parallel, but it behooves us to conduct more research that investigates what the issues might be, both from our own perspective as 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 lens 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 to 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 Baker (2020). For now, we have begun this important dialog 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 dialog. 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 (DiSalvo, Yip, Bonsignore, & DiSalvo, 2017; Illes et al., 2019; Walsh, Foss, Yip, & Druin, 2013). 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 approach is grounded in Nucci's work on the moral development (Nucci, Creane, & Powers, 2015) and Ryan and Deci's self-determination theory (Ryan & Deci, 2000), and informed by practices from VSD technical investigations (Friedman, Hendry, & Borning, 2017) and critical making (Ratto, 2011), all adapted for use with children. Critical making draws on recent work in HCI, including speculative and critical design (Dunne & Raby, 2013) and reflective design (Sengers, Boehner, David, & Kaye, 2005). 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 Antle et al. (2021), Dao-Kroeker, Antle, Kitson, Murai, and Adibi (2021), Murai et al. (2021).

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 dialog!

## 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 roles 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 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 dialog investigating the philosophical and social implications of recent developments in biowearables in order to open up a dialog within academia and industry about unique areas of ethical concern that must be considered now as this field emerges.

## 6. Selection and participation

There were no participants involved.

### Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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