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Human-Centered Design to Enhance Implementation and Impact in Health

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Abstract

Human-centered design (HCD) is an approach that aligns innovation development with the needs of the people and the settings where those innovations will be used. HCD is increasingly being applied across a variety of health domains, most often with the goals of translating research into real-world settings and expanding innovation adoption. This review introduces key HCD concepts, reviews the growth of HCD in public health and its alignment with the complementary field of implementation science, and details four prominent proximal outcomes of design processes: (a) usability, (b) user burden, (c) contextual appropriateness, and (d) engagement. For each outcome, we provide a definition and background, measurement options, and critiques and future directions. We conclude with a series of opportunities and challenges, including an inclusive big tent spanning different design traditions, pathways for enhancing HCD's scientific legitimacy, and explicit promotion of equitable design processes to improve individual, community, and population health.



CONCEPTUALIZING DESIGN AND HUMAN-CENTERED DESIGN FOR PUBLIC HEALTH

Public health has dramatically evolved to reflect interconnected biological, social, and environmental factors that affect health and well-being. We have never been better equipped to tackle large-scale health challenges, given remarkable advances in preventing and addressing disease and reducing mortality and morbidity (113, 118). And yet, despite having an array of evidence-based programs, practices, and policies (EBPs), we have consistently fallen short of successfully leveraging this knowledge to improve people's lives. Vaccine-preventable diseases such as polio persist, which we have failed to eradicate despite the existence of a vaccine for half a century. Similar challenges exist with delivering evidence-based prevention and treatment strategies for mental health problems; these challenges have inspired calls to embrace integrated, bottom-up translational research rooted in user needs, complex delivery systems, and cocreation processes (82). Person-centered health services that prioritize positive user experiences are a hallmark of high-quality health systems (60), which should account for individual, community, system, and policy factors that impact health status (122). Visions of public health that address complex health inequities and respect individuals' health rights necessitate methods through which to better address the needs of those affected by health systems and interventions.

Expanded use of human-centered design (HCD)—an approach that aligns innovation development with the needs of the people and settings that use those innovations—to support the development or redesign of EBPs is indicated in translational research, where users' lived experiences and needs are prioritized. In health contexts, HCD offers methods through which to engage individuals and communities receiving and facilitating care (17, 23, 69, 70) and to adapt EBPs for diverse contexts and cultures. This review introduces key HCD concepts, critically examines the growth of HCD in public health, and explores existing evidence for the impact of HCD on the proximal outcomes (e.g., usability, contextual appropriateness) that are critical for translating research into practice in real-world settings. In addition, we identify opportunities to better reach HCD's potential in supporting health equity and creating conditions where all individuals can attain the highest levels of health and well-being.

Diverse definitions and applications of HCD reflect the numerous fields that have contributed to its evolution. HCD's application in commercial, public, and research sectors has increased rapidly in the past decade, prompting an array of interpretations, emphases, and methods. Broadly, HCD is an approach to creating compelling, intuitive, adoptable, and engaging products, systems, and services (34). HCD's origins are inextricably linked with human factors engineering, human-computer interaction (HCI), and user-centered design (UCD). These three fields borrow from traditions of cognitive science and social and organizational psychology (70) to characterize interactions between individuals/communities and designs, especially in the context of digital technologies. Design work has also been popularized by the related concept of design thinking, a framework that conceptualizes design as a broad mindset and is commonly applied to social impact issues, including in public health (17), with mixed evidence for impact (31). At the broadest level, HCI, UCD, and design thinking are part of an umbrella of design concepts and communities that have been increasingly applied in health research. In this article, we use the term HCD to describe the design approaches discussed here because of its specificity, connection to concrete methods, and emphasis on humans (e.g., individuals, communities, and populations) that drive EBPs in public health.

An inclusive interpretation of HCD is advantageous when seeking to design technologies, interventions, and services in public health based on an assessment of user needs and contextual fit

(29). Although precision in language can facilitate collaboration within a team, recognition that terms such as design thinking and UCD are intimately related can broaden the methods and concepts from which a team might draw in their work. For example, methods from HCI have been used repeatedly in noncomputer technology contexts (74). The emerging domain of service design (97) demonstrates the broad applicability of some of these methods. While we provide a definition of HCD to guide our discussion, the HCD approach should not be defined solely by specific methods or design steps. Public health researchers should ultimately consider HCD as an adaptable approach in which the choice of methods, including how they are combined and adapted, is flexible. Advocating too strictly for a specific HCD definition or boundaries from the broader design family threatens our ability to leverage advances in methods and measures from individual subfields and compromises knowledge sharing.

RISE OF HCD IN PUBLIC HEALTH

HCD approaches have increasingly been applied across a variety of health domains, prompting dedicated reviews in such areas as human services (104), global health (8), HIV (11), mental health (117), and mobile health (50, 90). Unfortunately, such reviews are limited in scope due to adhering to strict definitions of HCD, and they often face the common limitation of studies failing to clearly define and report HCD processes (e.g., 8, 117). Such limitations hinder our ability to replicate HCD methods for other EBPs (8), as well as other challenges discussed later in this review. In addition to its use in these reviews, HCD has been used in studies of chronic disease prevention (80), pharmacy intervention development and refinement (33), social and economic conditions that drive inequities in infant mortality (115), and suicide intervention (61). Although HCD has been applied across a range of public health outcomes, indicating its flexibility, such studies are descriptive in nature and do not evaluate the impact of HCD approaches on implementation or user outcomes. HCD approaches have been used with both digital (e.g., mobile apps, websites) and nondigital interventions (e.g., complex services, implementation strategies), which aid in expanding the reach of evidence-based health care. While less of a focus has been placed on describing and evaluating how HCD has impacted public health workforce outcomes (e.g., workflow, efficiency), there are important exceptions. For instance, Norman et al. (91) assessed how HCD training for researchers—which focused on eliciting and integrating multiple perspectives and empathically engaging participants—enhanced a translational research team’s creativity, efficiency, project design, and products.

Problem Solving with HCD

Health researchers frequently turn to HCD to address critical problems they encounter. HCD approaches have most often been used to address challenges in intervention development or improvement (64, 112). In a large systematic review of 390 projects, Vaisson et al. (112) identified 283 projects that used HCD to develop patient decision aids/personal health tools. In a specific example, Flood et al. (33) applied HCD methods to develop an implementation support platform for a set of brief interventions targeting community health outcomes (e.g., alcohol use, healthy eating, physical activity). As described in greater detail below, other teams have applied HCD to address inadequate fit between an intervention and a setting, which has also involved efforts to address health inequities (30, 46). In this vein, Evans et al. (30) reviewed 32 digital health intervention studies, 75% of which applied HCD approaches to remove barriers associated with an intervention that would hinder a marginalized community from achieving a targeted health outcome. The review also found that HCD approaches were useful in some



studies to surface previously unidentified issues that exacerbate or maintain inequities in specific communities.

HCD and Implementation Science

Implementation science (IS), the study of methods to promote the uptake of research findings and EBPs into routine service delivery (28), has become a significant driving force in improving health and health care at scale (16). IS generally focuses on identifying and prioritizing barriers to and facilitators of EBP use (i.e., determinants) (21); selecting, tailoring, and evaluating implementation strategies (e.g., training, consultation) that actively promote intervention adoption, high-quality delivery, and sustainment (98); and evaluating implementation outcomes (100). HCD's focus on developing more usable innovations by considering multiple perspectives, collecting input from affected individuals and communities, and iteratively improving innovation-context fit is particularly well matched—and complementary—to the goals of IS (17, 70). When discussing HCD's application in the context of public health, it is therefore important to explicitly explore its intersection with IS.

The conceptual alignment and complementarity between HCD and IS have been well-articulated in the literature. Specifically, HCD methods can be used to assess implementation determinants (e.g., by identifying and prioritizing determinants across individuals, populations, policies, and systems), tailor strategies to improve their ease of use and usefulness, and evaluate implementation mechanisms and outcomes (especially usability, a unique construct from HCD; see below) (70). Discovery-oriented HCD work can help inform and operationalize implementation strategies (17). There are also more general opportunities to explore the alignment and integration of HCD and IS techniques (24). Most of the work at the intersection of HCD and IS has been unidirectional, seeking to integrate HCD into implementation research and practice initiatives, with very little work explicitly focused on the potential benefits of IS for HCD. In one of the few exceptions integrating IS into HCD for public health, Lyon and colleagues (69) explored and identified unrealized opportunities to pursue common objectives such as balancing innovative approaches to intervention engagement with preserving intervention fidelity, gathering and assessing proximal (e.g., contextual appropriateness) and distal (e.g., health status) outcomes throughout design and implementation processes, and translating knowledge from both fields to nonresearch audiences.

Researchers and practitioners have articulated multiple frameworks to leverage design methods and processes to explicitly advance IS objectives (e.g., EBP adoption), many of which have been built on foundational HCD frameworks (52, 87). For instance, the Discover, Design/Build, Test (DDBT) framework was developed by the University of Washington ALACRITY Center to facilitate implementation-focused development—or, more often, strategic redesign—of complex psychosocial interventions and implementation strategies, regardless of whether they have a digital technology component (76). Although DDBT was initially developed in the context of mental health EBPs, it is being increasingly applied throughout health care, such as to the development of a conversational agent to support smoking cessation (84) and the design of targeted prompts to help parents engage meaningfully in discussions of surgical care plans for their children (15). Designing for Dissemination and Sustainability (D4DS) (62) is perhaps the broadest of the design-focused implementation frameworks and seeks to apply techniques such as participatory codesign, marketing, and context/situation analysis to improve the likelihood that dissemination products (ranging from generalizable research evidence to policies and methods) will be adopted via strategic packaging and distribution. In sum, the connections and alignment between HCD and IS are already strong and seem destined only to deepen as HCD continues to gain traction in public health.

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METHODS USED IN HCD

Application of HCD involves using specific methods to directly inform and evaluate design solutions. A defining feature of a strong HCD study design is that methods are employed to systematically identify user and context needs, ideate and prototype solutions based on needs, and evaluate innovation-user and innovation-context fit (86). In public health, HCD has been most commonly applied to digital tools and products (2), but examples are increasingly emerging of HCD applied to more complex EBPs such as interventions for post-traumatic stress (74), voluntary modern contraceptive use among adolescents (27), or implementation strategies to support breast cancer screening (79). As with public health research, methods can be quantitative and qualitative, and the two are frequently combined to develop deeper insights (41).

A major appeal of incorporating an HCD approach in public health is the opportunity to draw on a wide range of methods, some of which are novel and others of which reflect alternative applications of familiar methods. Since some methods are borrowed from other fields and different interpretations of HCD vary in their methodological emphases, it is challenging—and often inappropriate—to claim specific approaches as HCD methods. Some methods are frequently used in HCD, however, including those that are not routine in public health research. For instance, prototyping (see below) is the creation of a preliminary version of an innovation or artifact for testing. Prototyping embodies HCD's emphasis on rapid iteration and embracing of failure by detecting design solution shortcomings early to inform subsequent iterations. Methods such as interviews, focus groups, literature reviews, field observation, and surveys are already widely used in public health; however, in HCD, these methods are typically carried out with the ultimate goal of making better design decisions (47). For example, interviews are frequently used as part of formative research to better understand behaviors and needs related to a design problem. Interviews can also be used as part of prototyping and are commonly coupled with other methods as part of usability testing (72). Although a discussion of the full array of design methods and techniques is beyond the scope of this review, readers are referred to Göttegens & Oertelt-Prigione (36), Hanington & Martin (41), and Dopp et al. (23) for more information. Below, we provide an example of a key practice in HCD: prototyping potential solutions or components of solutions. In **Table 1**, we offer a series of self-assessment questions that design teams might consider in order to avoid common pitfalls in the application of HCD in public health.

Prototypes help answer questions, propose potential designs, and communicate potential designs. Evidence supports their utility in improving the alignment of products with user needs and promoting usability (14, 35). Houde & Hill (48) describe three broad topics of prototypes: look and feel, implementation, and role. Any given prototype may support exploration of one or more of these topics, and, importantly, this separation of topics allows designers to first examine questions related to what a system should do (role) before figuring out how to build it, if it is even possible to build (implementation), and sensory experience (look and feel). In this way, prototypes may not even need to be, or depict, the actual system or service being built. For example, a storyboard depicting how an application (app) supports a user journey may never have to show the app to support better understanding of the desired role of that app.

Prototypes may be used exclusively within design teams or shown to potential users or other interested parties to elicit feedback. They may also exist at varying levels of fidelity, such as wireframes or sketches that can be produced quickly and inexpensively or full-fledged, interactive systems. Inexpensive lower-fidelity prototypes are typically used early in a process, where the speed and lower cost of producing these prototypes allow designers to explore a broader range of potential solutions. In addition, techniques exist to support evaluation of partial prototypes at higher levels of fidelity. For example, in “Wizard of Oz” prototyping, a human may perform key



Table 1 Design team self-assessment questions and solutions to ensure appropriate and effective use of HCD methods

Questions to assess an HCD process in health	Example approaches
Are you sharing decision-making (and associated resources) with the people who will use the system?	<ul style="list-style-type: none"> ■ Many teams use community-engaged methods, and there is a broad spectrum from community informed (e.g., solely data collection) to community led (e.g., selecting and applying methods), with different points on that spectrum fitting some projects better than others (43, 55). ■ If your work focuses on a specific direction, does the process have off-ramps or stopping points if you hear that it is not wanted (7) or realize it may do more harm than good?
Are you exploring multiple points in the design space?	<ul style="list-style-type: none"> ■ Prototype multiple possible solutions rather than a single preordained solution or direction (e.g., an app). ■ Make sure your approach includes opportunities to disconfirm the design team's assumptions or beliefs about what is needed or what will work.
Are you intervening at the desired scale/scope?	<ul style="list-style-type: none"> ■ Challenge design teams to consider upstream interventions for greater impact (116, 124), which is a strength of the public health field. For example, are there community-level interventions that might work better or more equitably than individual-level interventions? ■ Ensure that any individual-level interventions or design solutions fit within broader levels of health and prevention.
Might your product generate or reinforce inequities or otherwise cause harm?	<ul style="list-style-type: none"> ■ Ensure representative recruitment and/or over-recruit from historically marginalized communities. ■ Explicitly consider unintended consequences of a design solution (e.g., systems that collect personal health data in ways that expose people to inappropriate data sharing, such as through data brokers or government access (78). ■ Disaggregate results by demographics and examine disparate experiences with designs and/or impacts. ■ Track unintended consequences.
Are you using your resources efficiently and effectively?	<ul style="list-style-type: none"> ■ Consider mixing and adapting different user research and design approaches to best engage participants, inform your design process, and triangulate across data sources. ■ Review each planned design activity with a focus on how it will help the team make design decisions to determine whether it is essential. ■ Ensure your design process has flexibility to adjust iterations and participants based on what you learn (e.g., to pause and adapt if you are hearing the same thing repeatedly).

activities of a digital system (where the working version does not yet exist) to support exploration of questions about the role (81).

PROXIMAL OUTCOMES OF HCD

With the increasing use of HCD approaches for public health, it is important to review the common target outcomes of HCD as well as the extant evidence surrounding whether the HCD approach has been able to impact those outcomes consistently. HCD work may seek to improve a range of constructs, many of which might be considered elements of the broad concept of user experience (44). Various frameworks exist that guide designers in considering and measuring complementary, constituent concepts of user experience, such as the HEART (Happiness, Engagement, Adoption, Retention, and Task Success) framework for Web applications (103).

Below, we discuss four prominent proximal outcomes of contemporary design processes in health, which, when addressed, are theorized to subsequently improve the adoption and sustained



use of EBPs, thus enhancing health behaviors and promoting positive outcomes for target populations: (a) usability, (b) user burden, (c) contextual appropriateness, and (d) engagement. For each, we define the outcome and describe its importance, review measurement approaches that have been used in HCD (which include both qualitative and quantitative methods), and note important critiques and future directions.

Usability

Definition and rationale. Usability is the extent to which a system or service can be used by specific people to achieve specified goals with effectiveness, efficiency, and satisfaction within a specified context of use (51). Researchers and designers often focus on the summative evaluation of usability (that is, “is the resulting system usable?”) before evaluating other outcomes, but usability is a core consideration at all stages of the HCD approach. For example, identifying opportunities to make existing systems or practices more usable can inform an initial design problem and subsequent ideation of solutions. Centering usability in the design and prototyping process can also avoid costly mistakes, such as prematurely conducting a summative evaluation or finalizing a product that has significant and preventable usability issues.

Although usability as a concept has its origins in the application of psychology and an understanding of people’s cognitive capabilities in using computational systems, the concept has proven broadly useful for evaluating how people interact with systems and services (66), including in health care (42). Evaluating complex health interventions and implementation strategies through a usability lens, for example, can identify opportunities for improving how clients and clinicians should interact with the intervention as well as the supports that prepare people to successfully engage with an intervention (71, 86).

Measurement. Usability has been incorporated into various guidelines for intervention development, frequently without measurement guidance (121). For summative evaluations of prototypes or fully realized systems, usability is often assessed through a combination of metrics and usability testing. The ten-item System Usability Scale (SUS; 66) is the most commonly used scale with established benchmarks for scores above which usability concerns are not likely to interfere with adoption. Versions of the SUS have been developed for non-system-based health EBPs, including complex psychosocial interventions (77) and implementation strategies (72). The SUS is most useful for benchmarking intervention or system usability, but not for informing why a system has usability issues or for identifying specific opportunities for improvement. For this purpose, usability testing is often used (105). In usability testing, participants are observed while they interact with a service or system to complete prespecified tasks or engage in open-ended testing where they simply explore the system, often “thinking aloud” in the process (13). Given the range of health systems, interfaces, and interventions that could be the focus of usability testing, usability metrics and testing protocols may be customized for each public health project (74).

At more formative design and prototyping stages, practitioners often use usability evaluation to ensure that the design directions they pursue will result in usable systems. Approaches can include heuristic evaluation, in which experts examine a system with sets of heuristics for usable design (105). Various sets of heuristics exist (26, 63, 86, 89). A second approach, cognitive walkthroughs, involve in-depth review of the steps in an interaction (105). Adaptations of walkthroughs can be useful for identifying usability issues before prototyping a complex system, service, or intervention more fully (72).

Critiques and future directions. At a high level, many of the most salient critiques of usability might be described as arguing that it is necessary but insufficient on its own. While usability methods can evaluate whether any particular design is usable, they are insufficient for determining



whether a design solution is likely to be effective. Thus, usability evaluations may discourage creative but unfamiliar new approaches, find only local maxima, or fail to address questions about whether a given approach is ethical (25, 38). Furthermore, some specific approaches, such as cognitive walkthroughs, are typically less expensive to plan, conduct, and analyze than is usability testing, but they run the risk of producing false positives or missing usability issues, especially more complex ones.

User Burden

Definition and rationale. Public health innovations should avoid creating undue stress, disruption, or burden on those who adopt them [e.g., in the context of water, sanitation, and hygiene (WASH) interventions (49); needs for information for chronic illnesses (5); or dietary assessments (59)]. In implementation and public health research, studies of barriers to and facilitators of EBPs often identify user burdens that hinder adoption and effectiveness. User burden is defined as the negative impact that systems, tools, or products might place on the user (108). This definition includes foundational aspects of usability and user experience but also incorporates a diverse range of burdens in domains such as access, emotional, financial, mental/cognitive, physical, privacy, social, and time burdens. Such an expansive conceptualization of user burden aligns with broad conceptualizations of the many facets of user experience. User burden is typically conceptualized as affecting users both prior to and following adoption, in that high burden experienced from a system that has already been adopted can persist and negatively impact the user over time (108). In this way, user burden has relevance not just to the adoption of new innovations, but also to their sustained use in health systems.

Measurement. Research evaluating user burden is often focused on unintended negative consequences of using particular tools or products (58). The User Burden Scale (UBS) (108) is one of the few tools designed explicitly to address this concept. The UBS includes six aspects of user burden (difficulty of use, physical, time and social, mental and emotional, privacy, and financial burdens). To complement the UBS, a User Benefit Scale (18) has been developed to measure the positive impacts of novel systems and tools. When evaluating a range of non-health-related mobile apps, Cheng et al. (18) examined the differential prediction of aspects of user burden (difficulty and privacy) and user benefit. Findings indicated that user benefit was a better predictor of app use than was burden.

Critiques and future directions. Most references to user burden are anticipatory or theoretical. Although various studies have evaluated the relationship of user burden (and user benefit) to adoption and use of non-health-specific digital tools (18) or products such as personal protective equipment (102), we could not identify any studies that assessed the impact of HCD methods or processes on user burden as an outcome, and little research explicitly focused on user burden has been conducted in public health. Furthermore, some research suggests that burden might be negatively related to use in some situations but positively related in others. For instance, Turner-McGrievy et al. (111) completed a randomized trial of lower-burden and higher-burden methods for dietary assessment. Participants were randomly assigned to a wearable device or a photo-based tracking app (both lower burden) or a standard database app (higher burden). Results indicated that participants in the lower-burden conditions used their tools less, suggesting that lower burden might ultimately lead to lower engagement. Although user burden is typically conceptualized as negative, this study sheds light on the potential positive effects of higher user burden on adoption and sustained use.

Given the counterintuitive findings about the relationship between burden and use, caution is warranted surrounding efforts to reduce burden at all costs. Although excessive burden is likely

to interfere with uptake and sustained use of EBPs, some health care interventions require discomfort and burden to be effective. For instance, although exposure to feared stimuli is often uncomfortable for clinicians and patients alike (10), it has long been supported as one of the most effective elements of treatment for anxiety disorders such as obsessive-compulsive disorder (110).

Contextual Appropriateness

Definition and rationale. HCD is often ultimately concerned with ensuring that products fit users' contexts in ways that facilitate adoption and integration (12). This is also a strong point of intersection between HCD and IS (62), where contextual appropriateness has been more explicitly defined as the perceived fit, relevance, or compatibility of an innovation for a given setting and the individuals in that setting (99, 100). Consideration of contextual factors across intervention development, adaptation, and tailoring processes to improve the appropriateness of digital technologies, EBPs, and implementation strategies is often an explicit objective of the application of HCD (73, 95). For instance, Haines et al. (40) used contextual inquiry, usability testing, and iterative prototyping to develop implementation strategies intended to enhance the contextual fit and adoption of a care coordination intervention (40). In addition to designing products or innovations that align with the known constraints of a setting, contextual appropriateness can also be advanced by redesigning aspects of the setting (e.g., workflows) to be more conducive to particular types of products/innovations (i.e., social systems engineering) (96).

Measurement. Concrete tools applied in HCD to measure the degree to which health innovations align with their context of use have been drawn largely from the IS literature. Measurement is still limited, as documented in a systematic review that identified only seven instruments addressing appropriateness in physical health care (56). The Intervention Appropriateness Measure (IAM) (120) has been applied across a range of projects to evaluate the extent to which intervention or implementation strategy development or redesign projects result in improved fit with their target users and setting. For instance, when developing a digital implicit bias intervention for mental health clinicians working in schools, Liu et al. (68) used an IAM benchmark of >80% (i.e., an average score of 4+ on a 1–5 scale) among other indicators to confirm adequate appropriateness following iterative development and testing.

Critiques and future directions. Although ensuring that products fit the needs and settings of users is a major focus of HCD, applications in public health tend to incorporate attention to contextual appropriateness as a component of design processes and, outside of implementation research, are less likely to measure appropriateness explicitly as a design outcome. Much of this work is also emerging, such as a recently described (39) ongoing study that will iteratively develop and test prototypes of Hoosier Sport, a physical activity intervention for rural children in Indiana using IAM benchmarks. Overall, as HCD is increasingly applied across public health contexts, determining which design solutions—or parts of solutions—are broadly applicable and which are setting specific will be an important avenue for continued inquiry.

Engagement

Definition and rationale. User engagement can be defined as the emotional/affective (e.g., interest, value, valence), cognitive (e.g., motivation, effort), and behavioral (e.g., persistence, participation) connection that exists between a user and a product or innovation (4, 126). Researchers and practitioners have increasingly focused on engagement following the emergence of user experience within HCD, which has broadened and more explicitly incorporated less tangible factors such as emotion (6). However, there is little consensus across disciplines (54). Although more than



100 unique definitions of engagement have been identified (22), a recent scoping review focused on eHealth confirmed that behavioral, cognitive, and affective components were the most common (54). In mental health, failures of engagement at multiple levels (e.g., individual, system) have been identified as reasons why many digital therapeutics fail to be consistently implemented or sustained or to produce their intended effects (37).

Measurement approaches. Engagement is fundamentally complex, multidimensional, and challenging to measure. A meta-analysis of engagement conceptualizations and measurement in digital technologies (including, but not limited to, health) found that the majority of engagement measurement approaches take the form of questionnaires (e.g., User Engagement Scale; 94), behavior logging, or observations (22). Engagement is frequently evaluated based on downloads or time spent interacting with a product (e.g., number of visits to a website, minutes/hours of use), but this metric is often a proxy for determining whether the design is experienced as compelling, appealing, or useful (92). In a particularly sophisticated example of this approach, Taki et al. (109) developed an engagement index to assess the strengths and weaknesses of website and app features based on page views, frequency of use, engagement with push notifications, time between interactions, and subjective satisfaction. Although it did not originate in HCD, the Patient Responsiveness Scale (85) measures two factors—participation and enthusiasm—that map well onto some aspects of engagement. Although this scale focuses only on providers' perception of patient engagement, it has recently been adapted for administration to implementers and other users to report on their experiences with a variety of public health intervention and implementation strategies (75). In addition, given that complex conceptualizations of engagement generally extend beyond the quantity of interaction to the quality of experience, mixed methods are important for assessing this construct.

Critiques and future directions. Many studies have explicitly encouraged engagement as a characteristic of design processes, but these studies do not typically evaluate engagement as an explicit outcome of those processes (119). Furthermore, as noted above, engagement is sometimes measured behaviorally via indicators that are easy to collect (e.g., time interacting) but which might not reflect the important affective or cognitive components that are the true target of design processes. In addition, measures should be developed that capture engagement at different levels and from different perspectives of the health system (e.g., administrators, providers), but this literature is currently underdeveloped (123). Future work should continue to develop and clarify multifaceted conceptualizations of engagement and corresponding measurement models. Engagement can also wax and wane across phases of interventions or implementation efforts (e.g., in the case of digital psychotherapies; 93, 125), suggesting that approaches to understanding engagement should carefully account for time.

Summary of Proximal Outcomes

Although HCD processes are initiated in the context of health and public health projects to improve a variety of proximal outcomes, the strongest direct evidence for HCD's positive impact appears to be for usability and engagement. Overall, reviews of HCD from a health perspective have pointed out a need for more rigorous methods to consistently evaluate effects (32). Accrual of quantitative evidence for the impact of HCD methods and processes (e.g., via meta-analyses) has been relatively limited (53), making firm conclusions about "return on investment" (67) or the evidence for HCD difficult. Much of this limited evidence is due to the intractability of the question, Is a system/intervention designed through an HCD process better than one that was not? Whether they were trained in HCD or used methods that were articulated via an HCD lens, all designers of health interventions do so with human-centered intentions, making a clean

control condition of an undesigned intervention impossible. Instead, we are more often able to ask whether a design iteration leads to improvements compared with the previous intervention or whether one approach or strategy for design leads to different outcomes than does another. Furthermore, despite understandable pressure to demonstrate measurable, quantitative differences between one iteration or product and another, it is much more important to examine why people experience that product more or less positively to inform subsequent design—and redesign—decisions.

OPPORTUNITIES AND CHALLENGES FOR SUPPORTING HCD IN PUBLIC HEALTH

Enthusiasm for using HCD to improve public health has ushered in a surge of case studies spanning different health issues, interventions, implementation strategies, populations, and settings. The result is a rich potential evidence base to support HCD's value for health research and numerous critiques of limitations. These include concerns that HCD projects are merely trendy (46), prioritize innovation over realistic implementation (31, 114), are reductive (31, 83, 114), reinforce health and social inequities (1), lack standardized measurements (45), incorporate small sample sizes (83, 114), and overly emphasize users (83, 114). Applications of HCD in health are not without fault, such as anecdotal accounts of using HCD only to legitimize predetermined design solutions. Any research approach is only as good as its execution, and we believe that many of these issues can be traced back to how HCD is interpreted and applied (see **Table 1**). Optimizing HCD for health may be informed by lessons from the field of IS, which has seen similar rapid growth and formative hurdles (10). Over the past two decades, IS has made significant progress in developing methods, training, and reporting standards, but it continues to grapple with barriers such as (but not limited to) integrating siloed research, improving its scientific legitimacy, and addressing long-standing health inequities (16). In our work using HCD in public health and health care contexts, we see both parallel and unique struggles and propose recommendations below to help HCD reach its potential as an approach for improving health.

Embracing a Big Tent Approach to HCD

A holistic interpretation of HCD is critical to leverage methodological and measurement advancements born from the different traditions that contributed to HCD's evolution. Holeman & Kane (46) previously proposed an "HCD umbrella" that encompasses the many intersecting fields of design for health. Having some consensus on terminology can be valuable. However, adopting a narrow interpretation of HCD may also create barriers to knowledge sharing and growth. For example, health research is a rich space in HCI, yet HCI research is sometimes left out of reviews of design for health (46). Rather than focusing on developing a lingua franca for researchers and cross-disciplinary teams, we see value in advancing more informed HCD research questions, method selection, application, and adaptation, as well as investing in foundational scaffolding such as methods training opportunities. While HCD courses, certificate programs, and professional degrees exist, they are predominantly for beginners and frequently not optimized for researchers wishing to integrate HCD into health. A novice understanding of HCD can lead to inappropriate use of methods, unintended consequences, or a failure to effectively address user or contextual needs.

Improving Scientific Legitimacy

Public health historically prioritizes positivist epistemological tenets of objective, empirical evidence. Randomized controlled trials in which impact is evaluated by quantifiable metrics are



generally considered the gold standard for establishing effectiveness, and high-profile health journals often reflect monistic worldviews (57). HCD's embrace of uncertainty and dynamic iteration can cause tension when communicating with health researchers or funders who might have conflicting norms surrounding methods, timelines, and dissemination avenues. Despite these differences, we have seen numerous examples of successful integration of perspectives within teams, projects, grant applications, and published papers.

Explicit guidance on grant writing and dissemination for HCD public health research may be indicated to further build an empirical foundation for its impact. A challenge to this effort is the fragmented funding of HCD projects and the aforementioned diverse interpretations of HCD. In contrast, the field of IS benefits from substantial US National Institutes of Health funding, and funding announcements have been analyzed to identify patterns in expectations. Several IS grant proposal writing guides are informed by such analyses (20, 88, 101). Researchers have also proposed reporting guidelines on HCD health research, which are informed in part by qualitative health research reporting guidelines (9). Important aspects of the guidelines include specifying who was involved in the design process and critical decision points. Although these guidelines are specific to global health, they may be a starting point to discussing adaptation or expansion for broader use. Such guidelines might also be enhanced with explicit attention to which design ideas were intentionally not pursued, which is often just as informative as the final design direction.

Incorporating Equitable Design Approaches

Finally, although researchers invariably adopt HCD approaches with good intentions, there are numerous examples in which design processes insufficiently engage with communities, inadvertently reinforce power dynamics, and otherwise risk exacerbating—or newly creating—health inequities (116). As a result, there have been numerous calls by researchers and practitioners over the past decade to ensure that design practices are community led, address deep power structures, and prioritize doing no harm. These directions are particularly relevant in the context of health, where systemic inequities and social determinants of health are barriers to individuals attaining their highest potential levels of well-being. Health researchers have described high interest in using the HCD approach as a tool to promote health equity, and they have also discussed a host of simultaneous pitfalls and unintended consequences (30, 65, 106, 107). To facilitate the potential of HCD for supporting health equity, we encourage researchers to consider methods that align with a design justice framing. Design justice aims to “ensure a more equitable distribution of design's benefits and burdens; meaningful participation in design decisions; and recognition of community-based, Indigenous, and diasporic design traditions, knowledge, and practices” (19, p. 23). Related approaches include participatory design, value-sensitive design, universal design, inclusive design, pluriverse design, critical design, and speculative design. Examples of what these approaches may entail in practice could include adapting methods to account for user power dynamics in participatory research (19) or reflecting on whether users are meaningfully engaged in the design process using Arnstein's classic ladder of citizen participation (3). As a result, HCD methods can readily support an approach in which individual and community agency and engagement are prioritized in translational health research.

CONCLUSION

As public health needs continue to evolve, innovations to mitigate and address those needs must develop and advance. There are increasing opportunities to utilize HCD approaches to align innovation design and redesign with users' needs and the settings in which innovations will be



used. Beyond discussing key HCD concepts, expansion in public health, and evidence for impact, we have attempted to identify opportunities for researchers to broaden the reach of HCD and facilitate the continued integration and promotion of effective and equitable public health initiatives.

SUMMARY POINTS

1. Human-centered design (HCD) is an approach to creating compelling, intuitive, adoptable, and engaging products, systems, and services and is increasingly being applied to improve health and well-being for all.
2. HCD can be applied to the development or redesign of both digital and nondigital innovations and systems.
3. HCD's focus on developing more usable innovations by considering multiple perspectives, collecting input from affected individuals and communities, and iteratively improving innovation-context fit is well aligned with the goals of implementation science and health equity initiatives.
4. A defining feature of a strong HCD study design is that methods are employed to systematically identify user and context needs, ideate and prototype solutions based on needs, and evaluate innovation-user and innovation-context fit.
5. Proximal outcomes of HCD—the outcomes anticipated to lead to adoption and sustained use of new innovations—include usability, user burden, contextual appropriateness, and engagement.
6. Accrual of quantitative evidence for the impact of HCD methods and processes in public health has been relatively limited; the strongest evidence for its positive impact appears to be for usability and engagement.

FUTURE ISSUES

1. Adhering to narrow definitions of HCD may create barriers to knowledge sharing and growth, so adopting a holistic and inclusive interpretation that spans different design conceptualizations will be critical to leveraging methodological and measurement advancements.
2. HCD's scientific legitimacy in enhancing health may be advanced through explicit guidance on grant writing and dissemination of HCD research to support individual-, community-, and population-level health, including expanded reporting guidelines.
3. To facilitate the potential of HCD for supporting health equity, researchers should consider methods that align with a design justice framing.

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