

STATE-OF-THE-ART REVIEW

# Using Behavioral Economics and Technology to Improve Outcomes in Cardio-Oncology



Kimberly J. Waddell, PhD,<sup>a,b</sup> Payal D. Shah, MD,<sup>c</sup> Srinath Adusumalli, MD, MSc,<sup>b,c</sup> Mitesh S. Patel, MD, MBA, MS<sup>a,b,c,d</sup>

## ABSTRACT

Patients with cancer are often at elevated risk for cardiovascular disease due to overlapping risk factors and cardiotoxic anticancer treatments. Their cancer diagnoses may be the predominant focus of clinical care, with less of an emphasis on concurrent cardiovascular risk management. Widely adopted technology platforms, including electronic health records and mobile devices, can be leveraged to improve the cardiovascular outcomes of these patients. These technologies alone may be insufficient to change behavior and may have greater impact if combined with behavior change strategies. Behavioral economics is a scientific field that uses insights from economics and psychology to help explain why individuals are often predictably irrational. Combining insights from behavioral economics with these scalable technology platforms can positively impact medical decision-making and sustained healthy behaviors. This review focuses on the principles of behavioral economics and how "nudges" and scalable technology can be used to positively impact clinician and patient behaviors. (J Am Coll Cardiol CardioOnc 2020;2:84-96) Published by Elsevier on behalf of the American College of Cardiology Foundation. This is an open access article under the CC BY-NC-ND license (<http://creativecommons.org/licenses/by-nc-nd/4.0/>).

Advances in early detection and anti-neoplastic therapy have substantially reduced cancer mortality, resulting in a growing population of cancer survivors (1,2). Over the next decade, there are expected to be more than 20 million cancer survivors in the United States, and half will be over the age of 70 years (3,4). Cancer therapy-related cardiotoxicity is an increasingly recognized cause of morbidity and mortality for these individuals (5-10). Known cardiac side effects of

treatments, such as anthracyclines and human epidermal growth factor receptor 2 targeted agents, are augmented by overlapping risk factors for cardiovascular disease and cancer, such as obesity, tobacco use, and age. Childhood cancer survivors who live beyond 35 years of age have a 5-fold increased risk of stroke or myocardial infarction compared with healthy siblings (11). This risk is escalated in survivors with dyslipidemia, obesity, high blood pressure, or diabetes mellitus (11,12). Patients with cancer may

From the <sup>a</sup>Crescenzo Veterans Affairs Medical Center, Philadelphia, Pennsylvania, USA; <sup>b</sup>Penn Medicine Nudge Unit, University of Pennsylvania, Philadelphia, Pennsylvania, USA; <sup>c</sup>Perelman School of Medicine, University of Pennsylvania, Philadelphia, Pennsylvania, USA; and <sup>d</sup>The Wharton School, University of Pennsylvania, Philadelphia, Pennsylvania, USA. Dr. Waddell is supported by the Department of Veterans Affairs Advanced Fellowship Program in Health Services Research & Development (HSR&D). Dr. Patel is supported by a career development award from the Department of Veterans Affairs HSR&D; is founder of Catalyst Health, a technology and behavior change consulting firm; is an advisory board member for Healthmine Services Inc, LifeVest Health, and Holistic Industries; and has received research funding from Deloitte, which is not related to the work described in this manuscript. The contents of this manuscript do not represent the views of the U.S. Department of Veterans Affairs or the United States Government. All other authors have reported that they have no relationships relevant to the contents of this paper to disclose. Larry Allen, MD, served as Guest Editor for this paper.

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## HIGHLIGHTS

- Patients with cancer are often at increased risk of cardiovascular disease.
- Electronic health records and mobile devices are scalable technology platforms.
- Insights from behavioral economics combined with scalable technology platforms can nudge clinician decisions and improve patient behaviors.
- Combining technology with insights from behavioral economics can help address unmet needs of cardio-oncology patients.

experience clinical care that focuses on their oncological diagnosis with less of an emphasis on modifiable cardiovascular risk factors such as lack of physical activity and dyslipidemia (1). As cancer-related survival gains are made, greater attention is being directed toward understanding, preventing, and treating cardiac sequelae of anti-neoplastic therapy in a burgeoning population of cancer survivors.

A growing body of literature addresses surveillance and therapeutic strategies focused on the early detection and treatment of cardiotoxicity to help improve survivor outcomes (13-16). A significant unmet need is the optimal implementation of strategies that leverage principles of behavioral economics and scalable technology platforms to change clinician decisions and patient behaviors in a way that can positively impact cardiovascular outcomes among patients with cancer. Widely adopted technology platforms including electronic health records (EHR) and mobile devices could be better used to monitor and change clinician decisions and patient behaviors to improve cardio-oncology outcomes. The EHR design can significantly impact clinician decision-making and this creates an opportunity to implement interventions to improve medical decision-making (17,18). Smartphones and wearable devices can remotely monitor daily behaviors and biometrics including physical activity, heart rate, and sleep patterns. However, evidence indicates that these technologies alone are often not sufficient for changing behavior and could be more impactful if they were combined with effective behavior change strategies (19).

Behavioral economics is a scientific field that leverages principles from economics and psychology to help explain why individuals often make

suboptimal decisions that are not aligned with longer-term goals (20). Insights from behavioral economics can be combined with these scalable technology platforms to develop more effective interventions that lead to improvements in medical decision-making and sustained healthy behaviors (21).

In this article we describe how heuristics and cognitive biases influence medical decision-making and health behaviors. We highlight a growing body of evidence that demonstrates how to implement behavioral economic interventions through scalable technology platforms to change clinician decisions and motivate patients to engage in healthy behaviors. We provide recommendations for the field of cardio-oncology to combine technology with behavioral economics to improve cardiovascular outcomes for patients with cancer.

## PRINCIPLES OF BEHAVIORAL ECONOMICS

Behavioral economics incorporates concepts from economics and psychology to explain human decision-making (20,22). Standard economic theory assumes that individuals consistently synthesize available information and make rational choices that align with their longer-term goals (20). However, individuals are often unable to consistently synthesize complex information and make choices that maximize their longer-term outcomes. As a result, individuals rely on heuristics, or mental shortcuts, to help make decisions in their complex, daily environments. These heuristics can lead to cognitive biases that result in predictable decision errors (23). Insights from behavioral economics reveal patterns of irrational, predictable deviations that result in suboptimal decision-making. For example, individuals are motivated by immediate compared with delayed gratification (24,25), motivated more by avoiding losses than receiving equivalent gains (26), and often overestimate the probability of positive events while underestimating the probability of negative events (27,28). **Table 1** provides examples of common cognitive biases and their potential impact on clinician decisions, patient behaviors, and how to operationalize interventions to account for these biases.

The availability bias, or availability heuristic, explains why people miscalculate the likelihood of an event happening based on how easily an example or specific event comes to mind (23,29). For example, prior research has shown that physicians who recently encountered bacteremia in a patient were more likely to diagnose the condition in future

## ABBREVIATIONS AND ACRONYMS

- ASCVD** = atherosclerotic cardiovascular disease  
**CV** = cardiovascular  
**CVD** = cardiovascular disease  
**EHR** = electronic health record  
**DOAC** = direct oral anticoagulant  
**LVEF** = left ventricular ejection fraction

**TABLE 1 Cognitive Biases, Their Potential Impact on Clinician Decisions and Patient Behavior, and Intervention Strategies**

Cognitive Bias	Definition	Impact on Clinician Decisions	Impact on Patient Behavior	Behavioral Intervention
Availability bias	Relies on recent events when evaluating a decision or situation	Not implementing a comprehensive cardiotoxicity risk assessment prior to cancer treatment	Underestimating CVD risk due to limited information or prior exposure	Provide more immediate feedback on patient outcome that is otherwise unknown
Optimism bias	Overestimating probability of positive outcomes and underestimating probability of negative outcomes	Underestimating patient risk for adverse CV event	Underestimating risk of adverse CV event from cancer treatment	Frame information to accurately convey risk
Status quo bias	Preference for the current situation or things to stay the same	Low referral rates for diagnostic tests due to opt-in default	Not enrolling in medical management programs due to opt-in default	Set optimal choice as the default option
Present bias	Prefer immediate gratification compared with delayed gratification	Deprioritize CV surveillance to address immediate cancer attributable morbidity and mortality	Not achieving recommended amount of daily physical activity	Provide immediate feedback and reward preventative behaviors

CV = cardiovascular; CVD = cardiovascular disease.

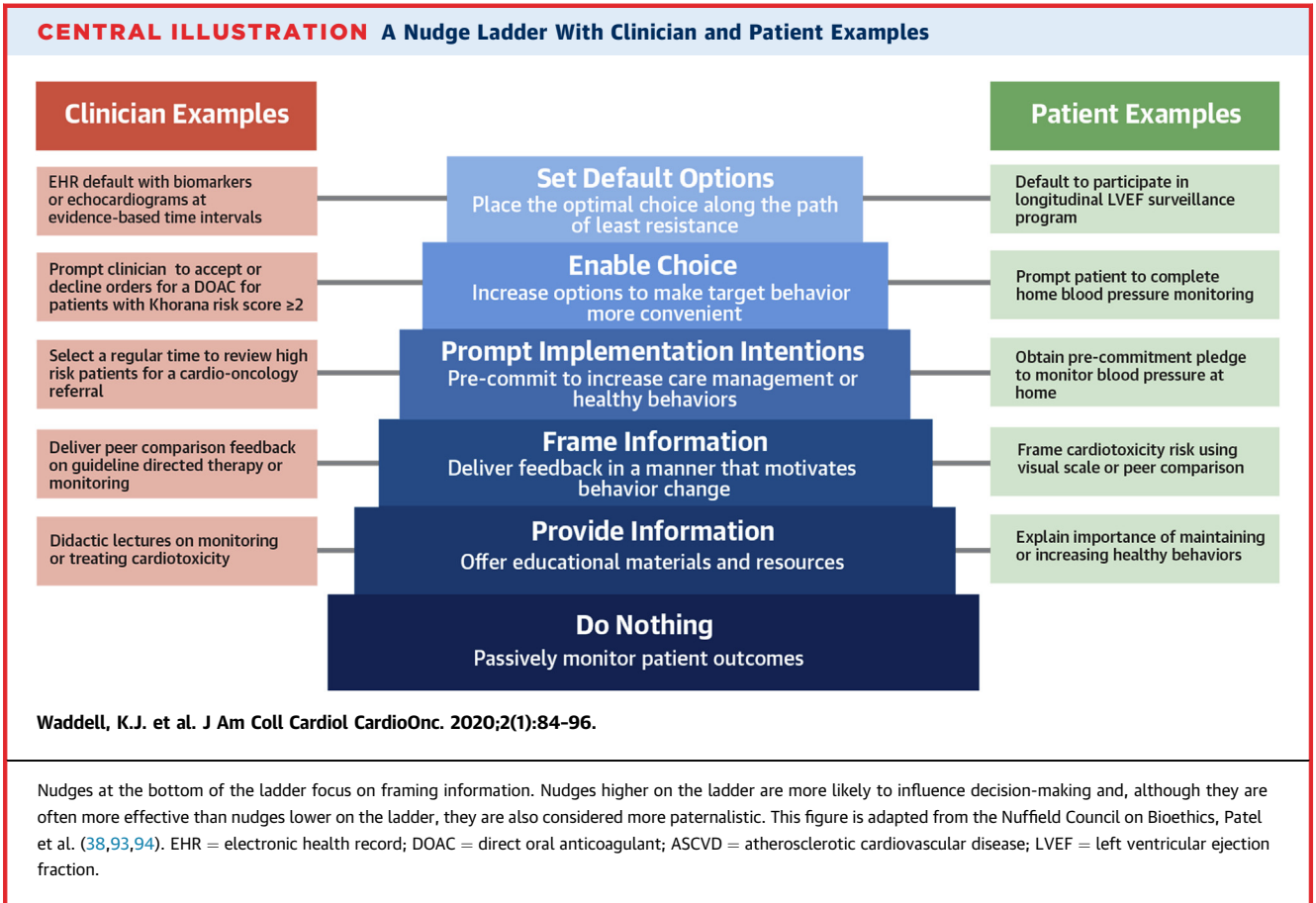
patients based on their previous exposure (30). Interventions that provide feedback on outcomes that are otherwise unknown or reviewed can help address availability bias. For example, mailing a notification letter to emergency medicine physicians when a patient for whom they had prescribed opioids died of an overdose resulted in a 10% reduction in opioid prescribing (31).

Optimism bias is defined as people's tendency to overestimate the probability of a positive event and underestimate the probability of a negative event happening in the future (27,28). Individuals regularly underestimate their probability of a negative health outcome, such as obesity, cancer, heart disease, or risk of cardiotoxicity related to cancer therapy. This may help explain sustained unhealthy behaviors; for example, individuals choose to smoke because they may grossly underestimate their odds of lung cancer in the future. Framing information in such a way that offers comparison feedback or accurately conveys risks can help account for optimism bias.

The status quo bias explains why individuals are more likely to stick with the default option when presented with alternative choices. The default option is the selected condition if no alternative is chosen (18,20,32). The default option, often considered the safe option, requires little energy and cognitive demand and strongly influences behavior (33). An opt-in default requires a person to actively choose to participate, whereas an opt-out default assumes participation unless an individual elects to opt-out of whatever intervention is offered. Interventions that place the optimal choice as the default choice can leverage status quo bias and have an outsized effect on decision-making. In healthcare, changing the default from opting into generic medications to opting out of them significantly increased generic prescription rates from 75% to 98%, which led to sustained effects (34,35).

Additionally, individuals tend to assign disproportionate weight to the immediate, present circumstance(s) and discount future events (24). Present bias is the inherent tendency to show a stronger preference for immediate gratification relative to delayed gratification (24). Present bias helps explain why many individuals choose immediate behaviors (snacking on unhealthy food) that may undermine their long-term health (obesity). Offering immediate performance feedback and/or rewarding preventative behaviors can help leverage present bias to improve behavior. For example, providing daily performance feedback regarding step goals coupled with loss-framed financial incentives resulted in a significant increase in physical activity levels for adults with ischemic heart disease (36).

These decision biases can be leveraged to help facilitate guideline-consistent clinician behavior and increase healthy patient behaviors (37,38). The behavioral economics field proposes an approach, termed asymmetric paternalism, to help improve human decision-making without restricting individual choice (20). The hallmark of asymmetric paternalism is helping individuals achieve their goals while not restricting choice or interfering with those who would otherwise make the optimal decision on their own (20,39,40). Subtle or simple changes to the choice environment that encourage the optimal decision without restricting choice are called nudges. Nudges can be designed to remind, guide, or motivate different behaviors and vary in strength and complexity (17). The **Central Illustration** provides a ladder of nudge interventions with examples of how nudges can be applied to cardio-oncology. The following section includes examples of how specific nudges can improve clinician decision-making and how previous research can inform the design and delivery of cardio-oncology nudge interventions.



### USING NUDGES TO IMPROVE CLINICIAN DECISION-MAKING

Over the last decade, EHR adoption among health systems and clinicians has increased from 20% to nearly 90% (41). As a result, decisions that were once made by paper or voice are now funneled through this technology platform. The EHR is a choice environment with clinical decision support embedded in the clinician’s workflow. For ongoing monitoring of complex conditions, such as cardiotoxicity or cardiovascular disease, there are multiple opportunities to develop scalable EHR interventions to facilitate guideline-consistent decisions over time (41). Prior evidence has demonstrated how nudges can be implemented while reducing clinician workload (42-46).

**FRAME INFORMATION.** Framing of choices or information to highlight the positive or negative features (e.g., emphasize gains vs. emphasize losses) can be an effective nudge that can alter behavior and the decision-making process (Central Illustration) (26). Additionally, framing performance feedback using

peer comparison data can also be an impactful nudge to improve decision-making and limit the effect of availability and optimism bias (Table 1). Individuals often measure their behavior by how far they are from the norm and frequently use peer norms to guide their own decisions (47). An unintended consequence of norming feedback, however, is that the descriptive norm (i.e., peer average) can cause regression toward the mean (“boomerang effect”) (47). To prevent this scenario, a recent randomized trial focused on improving statin prescribing used a tiered feedback approach and demonstrated a tripling in statin prescribing rates relative to usual care (43).

In the field of cardio-oncology, a framing intervention might be providing peer comparison feedback to increase rates of serial left ventricular ejection fraction monitoring for trastuzumab-related cardiotoxicity. Additionally, providing peer comparison feedback for prescribing appropriate medications for patients with baseline hypertension may help increase prescription rates among clinicians. For patients, showing their risk score for cardiotoxicity or likelihood of experiencing an adverse cardiovascular

**TABLE 2** Summary of Behavioral Economics and Physical Activity Studies

First Author (Ref. #)	N	Duration	Control Program	Intervention	Technology	Outcome	Result(s)
Chokshi et al. (36)	105	24 weeks	Passive monitoring of daily step count	Loss-framed financial incentives + personalized step goal	Wearable + daily feedback messaging	Change in mean daily steps during intervention period	Participants in financial incentive arm had significantly greater increase in mean steps per day compared with control (1,388 vs. 385)
Patel et al. (71)	200	24 weeks	Daily feedback if step goal was achieved or not	Control program + gamification	Wearable + daily feedback messaging	Proportion of days step goal was achieved	Participants in gamification arm achieved step goals on a significantly greater proportion of days (0.53 vs. 0.32)
Patel et al. (73)	602	36 weeks	Daily feedback from wearable	Control program + gamification with 3 arms: 1) competition; 2) support; 3) collaboration	Wearable + daily feedback messaging	Change in mean daily steps from baseline to end of intervention (24 weeks)	All gamification arms significantly increased their mean daily steps compared with control (920 competition, 689 support, 637 collaboration)
Patel et al. (69)	281	13 weeks	Daily feedback if step goal was achieved or not	Control program + 7,000 daily step goal + financial incentives where: Arm 1) gain-framed incentive; Arm 2) lottery incentive; Arm 3) loss-framed incentive	Smartphone + daily feedback messaging	Proportion of days step goal was achieved	Loss-framed financial incentive group achieved step goal on significantly greater number of days compared with control (0.16 adjusted difference)
Patel et al. (70)	304	26 weeks	Daily feedback if step goal was achieved or not	Control program + financial incentives where: Arm 1) individual; Arm 2) team; Arm 3) combined	Smartphone + daily feedback messaging	Proportion of days step goal was achieved	The combined incentive group achieved their step goal on a significantly greater number of days compared with control (0.35 vs. 0.18)
Patel et al. (72)	286	26 weeks	N/A	Social comparison feedback + financial incentives where: Arm 1) weekly feedback compared with 50th percentile; Arm 2) weekly feedback compared with 75th percentile; Arm 3) weekly performance feedback compared with 50th percentile + regret lottery; Arm 4) weekly performance feedback compared with 75th percentile + regret lottery	Smartphone + daily and weekly feedback messaging	Proportion of days step goal was achieved	The social comparison group compared with the 50th percentile with financial incentive (arm 3) achieved their step goal on a significantly greater number of days (0.18)

N/A = not applicable.

event, contextually framed with normative data may be an effective nudge to help increase motivation to improve healthy behaviors. An example could be contextualizing patients' risk score using a visual aide that has "very high risk, high risk, medium risk, low risk, or no risk" levels may effectively communicate the importance of healthy decisions and vigilant monitoring of their cardiovascular health.

**PROMPT IMPLEMENTATION INTENTIONS.** Prompting clinicians and patients to state their implementation intentions helps increase motivation (Central Illustration) (48,49). A commitment contract can help individuals bridge the gap between their current goals and future behaviors (48). Prompting clinicians to sign a pre-commitment pledge to order a cardiology referral for patients with malignancy or high atherosclerotic cardiovascular disease risk may

help bridge the gap between intention and behavior change. Asking patients to sign a pre-commitment pledge stating they will strive to monitor their blood pressure at home may help improve motivation and adherence rates for cardio-oncology patients. Given that the prevalence of hypertension is greater in oncology patients than the general population (50), remote monitoring of hypertension may improve disease management and potentially prevent adverse cardiovascular events (16,50).

**ENABLE CHOICE.** Nudges that enable choice (i.e., active choice) might require clinicians to make a decision in real time, rather than delaying the decision until later (Central Illustration) (46,51). Most active choice nudge interventions alert physicians (44,46) but this approach can cause alert fatigue. Such fatigue can be managed by shifting or redirecting the active

**TABLE 3 Summary of Behavioral Economics and Weight Loss Studies**

First Author (Ref. #)	N	Duration	Control Program	Intervention	Technology	Outcome	Result(s)
John et al. (95)	66	32 weeks	Dietician consult and monthly weigh-in	Control program + financial incentives using deposit contracts	Weight scale	Weight loss at 32 weeks	Intervention arm lost significantly more weight compared with control (8.7 lb vs. 1.2 lb)
Kullgren et al. (96)	105	24 weeks	Monthly weigh-in	Financial incentives where: Arm 1) individual financial reward (\$100) for meeting or exceeding weight loss goal; Arm 2) group financial reward (\$500) split between group members who met weight loss goal	Weight scale + automated text messaging	Weight loss at 24 weeks	Group incentive participants lost more weight compared with individual incentive and control conditions (9.7 lb)
Volpp et al. (97)	57	16 weeks	Monthly weigh-in	Financial incentive where: Arm 1) deposit contract with matching; Arm 2) lottery-based financial incentives	Weight scale + automated messaging	Weight loss at 16 weeks	Lottery financial incentive arm and deposit contract arm lost significantly more weight compared with control (13.1 lb and 14 lb vs. 3.9 lb)

choice nudge to a different medical team member (e.g., medical assistant or nurse). For example, a study evaluating cancer screening showed a 22% increase in breast cancer screening referral rates when medical assistants were trained to accept recommendations for cancer screening in patients who were due and then template an order for a physician to sign (51).

An active choice nudge intervention could be used to improve cardiovascular care for patients with cancer. Clinical practice guidelines recommend screening oncology patients for cardiotoxicity risk prior to treatment (14). Many documented risk factors (14) are structured within the EHR but exist in scattered locations. Indeed, a patient’s age, body mass index, smoking status, lipid profile, and comorbidities can exist in demographic, medical history, problem list, laboratory, or other sections. Cancer therapy drug and dose information are often in yet a different section such as an infusion flowsheet. Rather than creating a new screening assessment, a tool that is embedded within the EHR that integrates these existing risk factors into a single view with an incorporated risk stratification algorithm can identify patients at elevated risk for cardiotoxicity. If a patient is identified as having a high risk for cardiotoxicity, the medical assistant can receive an alert and make a real-time decision to template an order for a diagnostic test or cardiology referral for the physician to sign.

A second cardio-oncology active choice intervention could be integrating the Khorana risk assessment into routine practice using existing EHR data (52). This may help increase screening rates and prevent adverse thromboembolic events, an important

priority for the cardio-oncology field (15). The medical assistant can receive an alert when a patient is at high risk for a thromboembolic event and, in real time, accept or decline the option to template orders for the physician to sign during the patient’s visit. Such an instrument can save time during a clinical visit and reduce clinician EHR burden, both major limiting factors for implementing care interventions (53). This approach reduces friction along the decision-making pathway. For appropriate patients, issuing a remote monitoring blood pressure cuff and assisting with account or device set-up during their clinic may help improve remote blood pressure monitoring rates. Indeed, issuing a blood pressure cuff and asking patients to complete device set-up in real time (in-clinic) can prevent delayed decision-making and help increase in-home remote monitoring adherence rates. **SET DEFAULT OPTIONS.** Higher on the nudge intervention ladder is the use of default options (**Central Illustration**). This approach places the optimal decision along the path of least resistance and is often an effective nudge for facilitating evidence-based decisions when stakeholders have weakly held preferences and are unlikely to opt out (38). Currently, clinicians are required to enter, or “opt-in,” to such interventions like cardiology referrals or echocardiograms. Changing the default to automatically template referral or diagnostic orders for a clinician to review and sign versus filling in all the required information for every order can save time and facilitate the desired behavior.

For example, creating an EHR default pathway/order set with laboratory or imaging test orders at guideline-directed time intervals (e.g., echocardiograms every 3 months with trastuzumab therapy) may

**TABLE 4 Summary of Behavioral Economics and Smoking Cessation Studies**

First Author (Ref. #)	N	Duration	Control Program	Intervention	Technology	Outcome	Result(s)
Halpern et al. (98)	2,538	6 months	Issued local smoking cessation resources, cessation guides, behavioral modification program, nicotine replacement therapy	Financial incentives with: Arm 1) individual reward; Arm 2) individual deposit; Arm 3) collaborative reward; Arm 4) collaborative deposit	N/A	Sustained smoking abstinence at 6 months after target quit date	Rewards program resulted in higher abstinence rates (15.7%) compared with deposit program (10.2%) and control (6%).
Volpp et al. (99)	179	6 months	5 free smoking cessation classes	Control program + financial incentives (\$20 for attending class, \$100 if not smoking at 30 days post class completion)	N/A	Quit rate at 75 days	Financial incentive group had higher quit rate at 75 days compared with control (16.3% vs. 4.6%)
Volpp et al. (100)	878	18 months	Issued smoking cessation information	Control program + financial incentives (\$100 for completing cessation program, \$250 for sustained cessation at 6 months, \$400 for additional 6 months cessation)	N/A	Smoking cessation at 9 or 12 months, depending on initial cessation date	Financial incentive group had higher smoking cessation rate compared with control (14.7% vs. 5.0%)

Abbreviation as in Table 2.

help improve overall risk assessment rates and improve ongoing cardiovascular monitoring efforts. Changing the default order to no daily imaging during palliative radiotherapy significantly reduced unnecessary imaging during palliative care from 68.2% to 32.4% (54).

In many cases, it may not be possible to automatically set a default, such as engaging in a longitudinal surveillance program. In these cases, participation can be framed as opt-out. For example, a randomized trial framing colorectal cancer screening as opt-out versus opt-in tripled colorectal cancer screening rates over a 3-month period from 9.6% to 29.1% (55). Another randomized trial demonstrated significantly higher enrollment rates into a diabetes management program for the opt-out group (38%) compared with the opt-in group (13%) (56). The cardio-oncology field could use an opt-out framing approach to help improve enrollment into a longitudinal left ventricular ejection fraction surveillance program or the recently proposed concept of cardio-oncology rehabilitation (57). Changing the default from opt-in to opt-out of cardiac rehabilitation for appropriate patients resulted in significant increases in rehabilitation referrals (12% opt-in to 78% opt-out) (42).

Together, nudges embedded with the EHR can have a profound effect on clinician behavior without added cost or burden. Indeed, many of the above nudge interventions required little time to implement and had an outsized effect on rates of guideline-specific behavior. While nudges specifically target subtle or simple changes to choice architecture, there are additional principles of behavioral economics that can be leveraged to help facilitate healthy behavior change in patients.

## USING BEHAVIORAL ECONOMICS WITH SCALABLE TECHNOLOGY TO INCREASE HEALTHY PATIENT BEHAVIORS

Patients are influenced by irrational, yet predictable, behaviors that contribute to lack of physical activity, obesity, and other unhealthy behaviors (20,21). Helping patients to increase their physical activity, weight management, smoking cessation, and medication adherence during cancer treatment and survivorship may be one of the single most important investments to improve individual outcomes. Interventions to improve these modifiable risk factors are an important part of post-chemotherapy cardiotoxicity prevention (5,14,16,58,59). The evolution of wearable devices now provides individuals with immediate, constant access to an abundance of personal health data. Wearable devices accurately quantify daily physical activity levels (60) while also recording the quantity and quality of sleep, heart rate, and other behaviors. Pairing this technology with behavioral economic principles can help bridge the gap between quantifying and sharing information and sustained behavior change (19).

**PHYSICAL ACTIVITY.** Nearly 80% of US adults fail to achieve guideline-recommended physical activity levels (61), and the majority of cancer survivors remain inactive (62,63). Regular physical activity before, during, and after cancer treatment has been shown to reduce fatigue and improve overall physical health (64,65). Indeed, low cardiorespiratory fitness is associated with higher short- and long-term treatment-related cardiotoxicity, higher symptom burden, and an increased risk of all-cause and cancer-specific mortality (66-68). Recently, the concept of cardio-

**TABLE 5 Summary of Behavioral Economics and Medication Adherence Studies**

First Author (Ref. #)	N	Medication	Duration	Control Program	Intervention	Technology	Outcome	Result(s)
Volpp et al. (101)	1,509	Statin, aspirin, β-blocker, or antiplatelet agent	12 months	Standard of care	Issued electronic pill bottle + daily lottery incentive + supportive partner + access to social work resources + staff engagement advisor	Electronic pill bottles	Time to vascular rehospitalization or death	No difference between study arms in time to first rehospitalization or death (1.04 hazard ratio)
Volpp et al. (102)	20	Warfarin	3 months	N/A	Daily lottery incentives (\$10 reward or \$100 reward)	Computerized pill box + daily reminders	Proportion of incorrect warfarin doses	Proportion of increased pills taken significantly decreased from 22% to 2.3%
Linnemayr et al. (103)	155	Antiretroviral	9 months	Educational materials	Control program + small incentives (financial or prize)	Electronic pill bottles	Adherence rate	Incentive group was 23.7 percentage points more likely to achieve 90% adherence rate compared with control

Abbreviation as in Table 2.

oncology rehabilitation, analogous to cardiac rehabilitation, has even been proposed to improve cardiovascular outcomes for cancer survivors (57). A critical next step is designing and testing novel interventions paired with behavioral economics principles to help improve physical activity for cardio-oncology patients.

Designing novel physical activity interventions that leverage the principles of behavioral economics can help increase physical activity levels (36,69-73). Table 2 summarizes previous studies leveraging behavioral economic principles and technology to improve physical activity. These studies have deployed incentives, either financial or social, as a source of immediate gratification to leverage present bias (Table 1). Special consideration should be paid, however, to the framing of incentives when attempting to improve physical activity. Individuals will exert more effort to protect themselves against losses than gains, even when the two are equal (26,69).

Previous work has shown that loss framing increased physical activity relative to a control condition but gain framing did not (26,36,69,70,72). The key difference between loss and gain framing is that gain framing requires a patient to meet their goal prior to receiving a monetary, point-based, or other reward. Conversely, loss-framing initially endows an individual with a virtual incentive amount that the individual is at risk to lose if they do not achieve a particular objective.

The ACTIVE-REWARD clinical trial randomized patients with a history of ischemic heart disease to control or loss-framed financial incentives with personalized goal-setting to increase physical activity

(36). All participants received a wrist-worn wearable device to record daily steps. In the intervention arm of this trial, \$14 was allocated to a virtual account of a patient each week. Starting each week with a new deposit leveraged the fresh start effect, which is the tendency for aspirational behavioral around temporal landmarks (e.g., beginning of the year, month, or week) (74). If the patient did not meet a predetermined step goal each day, \$2 were removed from their account. Compared with the control arm, patients in the incentive arm had a significantly greater increase in steps throughout the intervention (1,388 vs. 385 steps) and follow up period (1,066 vs. 92 steps), even after removal of the financial incentive. Loss-framed financial incentives are effective at motivating behavior change but a key limitation is the cost associated with these studies. Social incentives have profound influence on health behaviors and can be leveraged through gamification interventions to increase physical activity (71).

Gamification uses game components (i.e., points, levels) in nongame contexts to help improve physical activity and other health behaviors (71,73,75-77). Gamification interventions can leverage loss aversion through points and levels in addition to social incentives through a variety of designs. For example, families who were enrolled in the Framingham Heart Study were randomized (as a family) into a 24-week study to increase physical activity (monitored with a wrist-worn wearable device) (71). Each family member selected an individualized step goal, received daily performance feedback, and signed a pre-commitment pledge stating that they would try their best to achieve their daily step goal. Families in



the gamification intervention received 70 points in a virtual account at the start of each week. Every day, an individual family member was randomly selected to represent their team. If the selected person did not meet their step goal, 10 points were deducted from the family account. If the selected person met their step goal, the family retained their points. At the end of each week, families that had at least 50 points in their account advanced a level and families with <50 points dropped a level. This gamification intervention leveraged accountability, peer support, and collaboration to help increase physical activity. Participants in the gamification arm met their daily step goal a significantly higher proportion of days compared with the control arm (0.53 vs. 0.32) and experienced a significantly higher change in average daily steps (1,661 vs. 636 steps) (71).

Gamification interventions that leverage social incentives by providing peer support, accountability, and even competition may be particularly beneficial because they can provide social support that may improve emotional and psychological health, important priorities for cancer survivors (78). Additionally, 1 in every 4 cancer survivors use a support group, which may serve as a unique space to design gamification interventions that leverage social support to increase physical activity or other modifiable risk factors (79).

#### **ADDITIONAL MODIFIABLE RISK FACTORS: WEIGHT MANAGEMENT, SMOKING CESSATION, AND MEDICATION ADHERENCE.**

Combining technology with behavioral economic principles is efficacious for improving weight loss, smoking cessation rates, and medication adherence. These modifiable risk factors influence cardiovascular outcomes for oncology patients and survivors to varying degrees (80-82). Healthcare systems, clinicians, and researchers who are interested in examining the efficacy of combining technology with behavioral economic principles to improve cardio-oncology outcomes can use previous research from cardiovascular and other clinical populations as a guide.

Obesity is a leading risk factor for cardiovascular disease and cancer, (83) and increased adiposity can result in higher mortality for nearly all types of cancers (81,82). Designing novel interventions that combine technology, such as weight scales with wireless syncing capabilities, with principles of behavioral economics (e.g., financial incentives) can result in a significantly greater weight loss compared with standard education interventions. Table 3 summarizes previous research that leveraged the principles of behavioral economics to improve weight loss. Of note, an ongoing trial is currently evaluating an

automated hovering intervention in adults with heart failure (84). This study uses electronic, wireless weight scales to monitor daily weight and electronic pill bottles to monitor diuretic adherence.

Smoking is the leading preventable cause of cancer and cancer mortality (85) and is a key risk factor for cardiovascular disease (86). Tobacco use negatively impacts cancer treatment and the length and quality of survival post-treatment (80). Table 4 summarizes studies that used behavioral economic principles to improve smoking cessation rates. These studies leveraged varying financial incentives that resulted in higher quit rates compared with standard educational interventions.

Historically, anticoagulant and statin adherence rates are alarmingly low in the general population (87-89). Nearly 60% of cardiovascular patients are nonadherent with medications (90). Table 5 summarizes available studies that leveraged principles of behavioral economics with electronic pill bottles and automated messaging to improve medication adherence rates. Results from these studies may benefit future research in the cardio-oncology field because the number of oncology patients and survivors receiving cardiovascular medications (e.g., statins) will likely increase over time.

#### **RECOMMENDATIONS AND FUTURE DIRECTIONS**

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The principles of behavioral economics can explain suboptimal decision-making and the underuse of guideline-based care while offering a framework for optimizing patient and clinician decisions. Selecting the right intervention requires thoughtful evaluation of the target behavior. The cardio-oncology field has recently identified several priorities, strategies, and behaviors important to the field, such as aggressively managing modifiable cardiovascular risk factors using a prevention framework (e.g., ABCDE framework), developing, deploying, and using evidence-based treatment protocols for cardiotoxicity, and accelerating the process of translating cardio-oncology research to practice (14-16). Each strategy/behavior will require a different behavioral economic intervention because there is no one size fits all approach. Furthermore, managing the care of oncology patients at high risk for cardiotoxicity is not a one-time event. The need for ongoing surveillance is clear. Using the EHR to embed nudge interventions can support both simple and complex decision pathways that are likely sustainable over time.

The field must extend considerable thought to the timing of patient interventions. Oncology patients at

the time of diagnosis and treatment are ill and managing a range of medical issues. Clinicians may want to consider testing a passive, remote monitoring program during the treatment phase using wearable devices or smartphone data. For example, patients can be approached using opt-out framing into a remote monitoring program and issued a wearable device if they do not already own one. For clinical purposes, approaching patient participation using opt-out framing will likely increase patient uptake of remote monitoring strategies; for research purposes, such opt-out defaults can contribute to a more diverse cohort (56,91). Behavioral and health data from wearable devices can potentially be transmitted to the EHR to aid in the detection and management of clinical indicators of cardiotoxicity. For example, a decrease in physical activity levels or an increase in average heart rate could indicate worsening cardiovascular parameters or health behaviors in the pre-symptomatic stage. Detecting these changes before the appearance of symptoms may be an indicator of subclinical cardiotoxicity and prompt expedited diagnostic testing, such as echocardiogram, and potentially help to reduce potential hospitalizations (84). Transmitted data could potentially alert a clinician prompting them to contact that patient and take the appropriate action. Remote monitoring and integrating wearable device data with the EHR is a relatively unexplored space but may be particularly beneficial for the ongoing surveillance of cardio-oncology patients. Future research can help determine optimal approaches for integrating health and behavioral data to the EHR, and what individual variables may be most informative in the remote monitoring of patients.

Robust interventions targeting modifiable risk factors that leverage the principles of behavioral economics may be best delivered post-treatment. Here, patients who successfully completed cancer treatment and are moving into survivorship may have increased motivation to improve their health (i.e., fresh start effect). In light of the recently proposed concept of cardio-oncology rehabilitation programs (57), novel interventions targeting modifiable risk

factors could be embedded within these programs to help improve patient outcomes.

Nudge interventions reach hospital systems, institutions, clinicians, and patients but require stakeholder investment. EHR nudges can often fall into the gap between quality improvement and research. Indeed, embedding experimentation into routine clinical practice is often a combined quality improvement and research effort that requires novel evaluation (92). As a result, embedding research teams within hospital systems who can systematically test the effectiveness of nudge interventions is essential. Nudge units are behavioral design teams that can help researchers and clinicians identify appropriate opportunities to deliver a nudge and when to choose a different path (17).

## CONCLUSIONS

There is a significant opportunity to improve cardiovascular outcomes for patients with cancer by combining scalable technology platforms and behavioral economic insights. Approaching the EHR as a choice environment, with thoughtful consideration to the design and presentation of choices, can promote optimal decision-making while reducing clinician burden. Mobile devices such as wearables can remotely monitor patient behaviors and be used to deploy behavioral interventions that leverage incentives and gamification. These approaches have been used successfully across a wide range of clinical domains. They will need to be adapted and designed specifically for patients with cancer. Because these approaches rely on widely used technology platforms, effective interventions could be scaled more broadly at lower cost and this creates significant potential to improve outcomes for patients with cancer.

**ADDRESS FOR CORRESPONDENCE:** Dr. Kimberly J. Waddell, Crescenz Veterans Affairs Medical Center, 423 Guardian Drive, Blockley Hall 1005, Philadelphia, Pennsylvania 19104. E-mail: [Kimberly.Waddell@pennmedicine.upenn.edu](mailto:Kimberly.Waddell@pennmedicine.upenn.edu). Twitter: [@kwaddell022](https://twitter.com/kwaddell022), [@miteshpatel](https://twitter.com/miteshpatel), [@sriadu](https://twitter.com/sriadu).

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