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Design-Led Intervention to Reduce Sedentary Behavior in Young People

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Abstract
Physical inactivity has been a predominant cause of major chronic health problems. In 2020 the World Health Organization (WHO) issued revised guidelines on physical activity and sedentary behavior for children to encourage a more active lifestyle. However, due to the growing trends of digital culture, children at a young age are exposed to increased screen-related sedentary activities. We add to this endeavor by considering creative ways to promote an active lifestyle to reduce the risks associated this. In this paper we report on a design-led intervention that was applied to increase physical activity and reduce sedentary time in the home environment. We also discuss the effectiveness of this intervention on regulating changed behavior. Data were gathered from 20 households' participants over 12 weeks using a novel prototype called the Knudgebox. This is a program where physical activities are a condition to have screen access. This prototype was designed to facilitate active self-regulation to reduce sedentary behavior instead of stimulating a new behavior change through extrinsic benefits. Our results show that an increase in physical activities and a decrease in screen time can be achieved using the Knudgebox. We identified new behavioral patterns and insights regarding how design elements affected their determinants in taking changed behavior from triggered to self-regulation.

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Introduction

Many people would have taken the outbreak of the Covid-19 pandemic to rethink how they spent their time at home. In doing so, they may agree that screen time has increased throughout this period. They may also agree that maintaining a healthy weight was more difficult at that time. Admittedly, screen usage has played a critical role in enabling people to work from home, be educated, and relieve stress through watching entertainment. However, more screen time may have caused people to be inactive during these extended times. This raises concerns about the resulting lack of physical activity being a factor that has led to an increase in obesity.

The World Health Organization (WHO) has labelled obesity as an epidemic or pandemic health problem.[1] Among the factors that contribute to increased obesity, physical inactivity is a significant one. I-Min Lee and her colleagues[2] suggest that physical inactivity kills more people each year than tobacco smoking. Behavior associated with physical inactivity has been researched. Findings suggest that connection between changing such behavior and encouraging ambulatory movement could contribute to the solution to the problem of obesity.[3] That connection merits further investigation.

Staying healthy from a young age is vital for the purpose of long life. Children who are overweight or obese are more likely to grow into overweight or obese adults, suffering from physical and mental illness and having a lower quality of life from childhood through adulthood. Although the increase in overweight and obesity cases among children and young people has leveled out since 2004, there has been no decline.[4] Meanwhile, the number of children and young people who remained physically active during the Covid-19 pandemic declined in 2019–2020 academic year.[5] For the previous three decades, television had been considered harmful for the health of children and adolescents.[6] The World Health Organization[7] recommend that parents should limit the screen exposure of children with consistent limits on sedentary screen time. They recommend that 2- to 4-year-olds should not have more than one hour per day and no screen time for children under two years.

Screen time in itself may not be the only cause of harm; the associated effects of displacing opportunities for more positive behaviours such as socialising, engaging in exercise and sufficient sleep may also contribute to harm. Physical inactivity associated with excessive screen time has drawn increasing attention in public health. For example, a study suggests that clustered lifestyle behaviors varying from reduced physical activity, excess screen time activities, and too much sitting—also known as sedentary behavior—are all contributors to the global obesity epidemic.[8] WHO also supports the position that physical inactivity has been a predominant cause of major chronic health problems, including, but not limited to, obesity, cardiovascular diseases, and diabetes.[9] Given this, the United Kingdom's Department of Health and Social Care guidelines recommend engagement of up to 60 minutes of moderate to vigorous physical activity daily for people aged 5–18 years.[10] However, the current situation stands in stark contrast to such a recommendation. According to the British Heart Foundation report published in 2017, a significant number of young people do not participate in sufficient physical activity.[11]

1 World Health Organization, *Global Status Report on Noncommunicable Diseases 2014* (Geneva: World Health Organization, 2014), https://apps.who.int/iris/bitstream/handle/10665/148114/9789241564854_eng.pdf.

2 I-Min Lee et al., "Effect of Physical Inactivity on Major Non-communicable Diseases Worldwide: An Analysis of Burden of Disease and Life Expectancy," *Lancet* 380, no. 9838 (2012): 228, https://doi.org/10.1016/S0140-6736(12)61031-9.

3 Stuart Biddle et al., "Sedentary Behaviour and Obesity: Review of the Current Scientific Evidence" (report, commissioned by Department of Health's Cross Government Obesity Unit, 2010), 30–39, https://openresearch.surrey.ac.uk/esploro/outputs/99516793902346; Susan Silverstone and Jim Teatum, "Technology: The Problem or the Solution to Childhood Obesity," *American Journal of Business Education* 4, no. 1 (2011): 37–60, available at https://core.ac.uk/download/pdf/268108945.pdf.

4 Population Health Analysis, "Child Obesity: Patterns and Trends" (slides, onlined by Public Health England, 2020), https://www.gov.uk/government/publications/child-obesity-patterns-and-trends.

5 Sport England, "Active Lives Children and Young People Survey: Academic Year 2020–21" (report, presented for children and young people in school Years 1–11 in England, 2021), https://sportengland-production-files.s3.eu-west-2.amazonaws.com/s3fs-public/2021-12/Active%20Lives%20Children%20and%20Young%20People%20Survey%20Academic%20Year%202020-21%20Report.pdf?VersionId=3jpdwfbsWB4PNtKJGxwbyu5Y-2nuRFMBV.

6 American Academy of Pediatrics, "American Academy of Pediatrics: Children, Adolescents, and Television," *Pediatrics* 107, no. 2 (2001): 423–26, http://www.ncbi.nlm.nih.gov/pubmed/11158483.

7 World Health Organization, *Guidelines on Physical Activity, Sedentary Behaviour and Sleep for Children under 5 Years of Age* (Geneva: World Health Organization, 2019), 11.

8 Sophie Cassidy et al., "Cross-Sectional Study of Diet, Physical Activity, Television Viewing and Sleep Duration in 233 110 Adults from the UK Biobank; the Behavioural Phenotype of Cardiovascular Disease and Type 2 Diabetes," *BMJ Open* 6, no. 3 (2016): e010038, p. 1–2, https://doi.org/10.1136/bmjopen-2015-010038.

It is timely then, to reconsider how our everyday lives are being transformed with the use of technology.[12] Such reconsideration, in our current study, shows a trend in the use of modern screen devices that will have detrimental effects on health. We argue that it is necessary to change screen device usage while restoring physical activity. This sort of trend in post-Covid-19 lifestyles needs to be challenged. We designed a tool to bring a behavioral change associated with screen time usage at home. We focused on youth and their screen-based sedentary behaviors within the home environment. We evaluated this tool as it explored an alternative strategy of employing behavioral intervention by reducing sedentary behavior and by encouraging children at home to self-regulate active behavior to improve health outcomes.

Changing Behavior through Design

There has been an increase in published research in the field of behavioral economics and persuasive technology, contextualizing the role of technologies and their influence on behavior.[13] The design for behavioral change helps us understand how design can create desirable and undesirable changes in behavior. Researchers have, in response, focused on design strategies for behavioral change, with an emphasis on delivering empirically grounded ideas addressing conscious and unconscious behaviors.[14] They have proposed a matrix with which to map behavioral problems better using design approaches.[15] In more recent years, design for sustainable behavior has emerged as both a research field and a practice to reduce the environmental and social impact, for example, good health, by moderating user behavior. A design for sustainable behavior approach is used to investigate behavioral problems and propose solutions that bring a change that achieves a more sustainable outcome during the use phase of products, services, or systems.[16] This field of design research has gained interest within the last decade; the field still needs an empirical framework to gain strength in the research world. Recent studies in this field have attempted to identify various types of intervention strategies so that they can be more effectively mapped against behavior problems and their users' willingness to change.[17] They have also been used to suggest a matrix that is based on behavioral constraint or demand for change.[18] Our review of the literature leads us to argue that further research should be undertaken, particularly for improving the knowledge through testing the effectiveness of suggested strategies. The effects of such empirical studies would be to advance methodological understandings in design for sustainable behavior, its mode of delivery, and to evaluate its interventions for their effectiveness.[19]

The Role of Feedback

In the field of design for behavioral change, designers tend to script information to ensure that users can predict any benefits, incentives, and rules attributed to the design-led intervention. The script approach is a conventional design strategy for prompting an intended behavior.[20] Jaap Jelsma and Marjolijn Knot's idea of the script is to influence the user's behavior through

9 World Health Organization, *Global Status Report on Noncommunicable Diseases 2014*.

10 Dame Sally C Davies et al., "UK Chief Medical Officers' Physical Activity Guidelines" (report, Department of Health and Social Care, 2019), available at https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/832868/uk-chief-medical-officers-physical-activity-guidelines.pdf.

11 British Heart Foundation, "Physical Inactivity and Sedentary Behaviour Report 2017" (report, British Heart Foundation, 2017), 125, https://www.bhf.org.uk/informationsupport/publications/statistics/physical-inactivity-report-2017.

12 Silverstone and Teatum, "Technology," 56–57.

13 Kristina Niedderer et al., "Creating Sustainable Innovation through Design for Behaviour Change" (report, Arts and Humanities Research Council, 2014), 9, https://wlv.openrepository.com/bitstream/handle/2436/336632/?sequence=1.

14 Philip J. Cash, Charlotte Gram Hartlev, and Christine Boysen Durazo, "Behavioural Design: A Process for Integrating Behaviour Change and Design," *Design Studies* 48 (January 2017): 96–128, https://doi.org/10.1016/j.destud.2016.10.001.

15 Philip Cash et al., "Designing Behaviour Change: A Behavioural Problem/Solution (BPS) Matrix," *International Journal of Design* 14, no. 2 (2020): 77, http://www.ijdesign.org/index.php/IJDesign/article/view/3952.

16 Fabrizio Ceschin and Idil Gaziulusoy, "Evolution of Design for Sustainability: From Product Design to Design for System Innovations and Transitions," *Design Studies* 47 (November 2016): 118–63, https://doi.org/10.1016/j.destud.2016.09.002; Aykut Coskun, John Zimmerman, and Cigdem Erbug, "Promoting Sustainability through Behavior Change: A Review," *Design Studies* 41 (November 2015): 183–204, https://doi.org/10.1016/j.destud.2015.08.008; Debra Lilley et al., "Design Interventions for Sustainable Behaviour," in *Design for Behaviour Change: Theories and Practices of Designing for Change*, ed. Kristina Niedderer, Stephen Clune, and Geke Ludden (London: Routledge, 2017), 427–445, https://doi.org/10.4324/9781315576602; Dan Lockton, David Harrison, and Neville A. Stanton, "Exploring Design Patterns for Sustainable Behaviour," *Design Journal* 16, no. 4 (2013): 431–59, https://doi.org/10.2752/175630613X13746645186124; Anneli Selvefors et al., "Designed to Support or Impede Energy Conservation? How Design Characteristics

Influence People's Energy Use," *Journal of Design Research* 15, no. 1 (2017): 43–61, https://doi.org/10.1504/JDR.2017.084504; Garrath T. Wilson, Tracy Bhamra, and Debra Lilley, "The Considerations and Limitations of Feedback as a Strategy for Behaviour Change," *International Journal of Sustainable Engineering* 8, no. 3 (2015): 186–95, https://doi.org/10.1080/19397038.2015.1006299.

17 Nynke Tromp, Paul Hekkert, and Peter-Paul Verbeek, "Design for Socially Responsible Behavior: A Classification of Influence Based on Intended User Experience," *Design Issues* 27, no. 3 (2011): 8–14, https://doi.org/10.1162/DESI_a_00087.

18 Cash et al., "Designing Behaviour Change," 77.

19 Marta M. Marques et al., "Delivering Behaviour Change Interventions: Development of a Mode of Delivery Ontology," *Wellcome Open Research* 5 (February 2021): article no. 125, https://doi.org/10.12688/wellcomeopenres.15906.2; Susan Michie et al., "Behaviour Change Techniques: The Development and Evaluation of a Taxonomic Method for Reporting and Describing Behaviour Change Interventions (A Suite of Five Studies Involving Consensus Methods, Randomised Controlled Trials and Analysis of Qualitative Data," *Health Technology Assessment* 19, no. 99 (2015), https://doi.org/10.3310/hta19990; Kristina Niedderer et al., "Design for Behaviour Change as a Driver for Sustainable Innovation: Challenges and Opportunities for Implementation in the Private and Public Sectors," *International Journal of Design* 10, no. 2 (2016): 67–85, http://www.ijdesign.org/index.php/IJDesign/article/view/2260.

20 Jaap Jelsma and Marjolijn Knot, "Designing Environmentally Efficient Services; A 'Script' Approach," *Journal of Sustainable Product Design* 2 (2002): 120, https://doi.org/10.1023/B:JSPD.0000031031.20974.1b.
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21 Donald A. Norman, "Affordance, Conventions, and Design," *Interactions* 6, no. 3 (1999): 39, https://doi.org/10.1145/301153.301168.

22 Richard Buchanan, "Declaration by Design: Rhetoric, Argument, and Demonstration in Design Practice," *Design Issues* 2, no. 1 (1985): 6, https://doi.org/10.2307/1511524.

23 Madeleine Akrich, "The De-scription of Technical Objects," in *Shaping Technology/Building Society*, ed. Wiebe E. Bijker and John Law (Cambridge, MA: MIT Press, 1992), 205–24, available at https://pedropeixotoferreira.files.wordpress.

value incentives or rules scripted, for example, feedback, in building the service of the product. Donald Norman uses the notion of perceived affordance to explain how a scripted design approach allows the user to perceive a certain action with a known outcome in mind.[21] It has also been argued that all designs have been constructed with an intention to influence or change human behavior.[22] This suggests that all artifacts around us have been socially scripted for users during the design process.[23] If a bin, for instance, is positioned on the street, we are influencing a user to follow the script and put their rubbish in the bin. Yet, some systems are also designed in such an abstract way that requires the user's conscious engagement to cooperate with the designer's intention. The user's ability to engage with the product in this case will relate to designer's intention and appropriation.[24] This suggests that the designer's intention does not always correspond with the user's behavior. When the user successfully repeats the intended behavior over a period of time, that behavior will be routinized. At the same time, users can evaluate their motivations and other elements, such as the benefits of their new behavior, which then becomes a crucial part of maintaining that changed behavior.

Gert Spaargaren argues that the most important aspect of behavioral change is the process of re-routinising the changed behaviors. He also argues that one-sided emphasis on an intention, attitudes, or individual motive is only effective in the short-term.[25] Corinna Fischer also explains that a conscious decision is to be made for new norms and considerations to enter the decision-making process, meaning that previous habits must be broken up somehow.[26] This process, called norm activation stage, draws on the notion of altruistic behavior proposed by Shalom Schwartz.[27] Here, the person realizes that there are various options to choose from, making their behavior relevant to the problem, and making them conscious that it is possible for them to influence and change their behavior. A similar notion is emphasized by Richard Thaler and Cass Sunstein[28] in their nudge theory, in which they employ a continuous reciprocal interaction between choice architecture and personal motivations to encourage pro-social behavior. The concept of positive reinforcement in shaping behavior is part of nudge theory where behavior change is influenced by choice rather than legislation or punishment. Feedback is one such means to influence the direction the user may take.

Persuasive technology, pioneered by Brian Fogg, also uses the function of feedback to bring a behavior change.[29] Persuasive technology draws on theories from psychology and behavioral economics to focus on how motivation, ability, and triggers (prompts) can encourage or discourage the user to act in the desired way. He describes triggers as something that reminds the individual that it is time to act, which in design terms, can be utilized by the function of feedback. Still, these kinds of contextual cues are only responsive when the right level of an individual's motivation is sufficiently inclined to change and sustain the behavior. Persuasive technology is an approach which utilizes technology to change an individual's attitude or behavior in a way determined by the designer through features scripted by that designer. Fogg suggests, that similar to norm activation, a trigger is a

com/2014/03/akrich-the-de-scription-of-technical-objects.pdf.
24 Antti Salovaara, "Inventing New Uses for Tools: A Cognitive Foundation for Studies on Appropriation," *Human Technology: An Interdisciplinary Journal on Humans in ICT Environments* 4, no. 2 (2008): 213–14, https://doi.org/10.17011/ht/urn.200811065856.
25 Gert Spaargaren, *The Ecological Modernization of Production and Consumption: Essays in Environmental Sociology* (Wageningen, NL: Wageningen University and Research, 1997), 126, https://edepot.wur.nl/138382.
26 Corinna Fischer, "Feedback on Household Electricity Consumption: A Tool for Saving Energy?," *Energy Efficiency* 1, no. 1 (2008): 81–82, https://doi.org/10.1007/s12053-008-9009-7.
27 Shalom H. Schwartz, "Normative Influences on Altruism," in *Advances in Experimental Social Psychology*, ed. Leonard Berkowitz (New York: Academic Press, 1977), 222–24, https://doi.org/10.1016/S0065-2601(08)60358-5.
28 Richard Thaler and Cass Sunstein, *Nudge: The Gentle Power of Choice Architecture* (New Haven: Yale University Press, 2008).
29 Brian Fogg, "Persuasive Technology: Using Computers to Change What We Think and Do," *Ubiquity* 2002 (December 2002): 89–120, https://doi.org/10.1145/764008.763957.
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30 Brian J Fogg, "A Behavior Model for Persuasive Design," in *Proceedings of the 4th international Conference on Persuasive Technology* (New York: ACM, 2009), article no. 40, p. 1–2, https://doi.org/10.1145/1541948.1541999.
31 Hyunjae Daniel Shin and Richard Bull, "Three Dimensions of Design for Sustainable Behaviour," *Sustainability* 11, no. 17 (2019): article no. 4610, p. 5–7, https://doi.org/10.3390/su11174610.
32 Johannes Zachrisson and Casper Boks, "Exploring Behavioural Psychology to Support Design for Sustainable Behaviour Research," *Journal of Design Research* 10, no. 1-2 (2012): 60, https://doi.org/10.1504/JDR.2012.046139.
33 Dan Lockton, David Harrison, and Neville A. Stanton, "Models of the User: Designers' Perspectives on Influencing Sustainable Behaviour," *Journal of Design Research* 10, no. 1-2 (2012): 13, https://doi.org/10.1504/JDR.2012.046137.
34 Renee Wever, Jasper van Kuijk, and Casper Boks, "User-Centred Design for Sustainable Behaviour," *International Journal of Sustainable Engineering* 1, no. 1 (2008): 13–14, https://doi.org/10.1080/19397030802166205.

key factor for the target behavior to occur repeatedly. If the trigger is absent, the behavior change is unlikely to occur, regardless of how high the motivation and ability are.[30]

Hyunjae Shin and Richard Bull, like Fogg, have emphasized the important role of feedback in bringing an effective behavioral change as it connects and develops the relationship between actors (users) and objects (design-led intervention).[31] They present the notion of the *feedforward* function. This function allows users to receive consequential information about changed behavior. It can also lead them to select new actions that are based on future scenarios or predictions of a future state that can be speculative. People are going through a learning process where information (feedback and feedforward) challenges their previous choices, and they adjust themselves to exercising a different choice in practice. This in turn can help the individual self-regulate their newly established behavior. In design for sustainable behavior studies, these strategies have been referred to as persuading,[32] self-regulating,[33] scripting,[34] and behavior steering.[35] Such strategies are used to maintain changed behavior by promoting regulation or repetition of actions prompted by external benefits like reward or emotion.

Self-Regulation

According to Giddens, habits are part of routine performance of daily activities going through actions of practical consciousness that are repeatedly performed and familiarized in daily life.[36] These habits are sometimes reinforced through actions of discursive consciousness where people have abilities to examine and evaluate their behavior through reflection on social discourse, such as information campaigns. Behavioral economics helps explain people's everyday decision-making as it recognizes that an individual's decision is based on psychological, emotional, cognitive, and social demands.[37] This indicates that human behavior could also be biased. Researchers argue that these biases could be leveraged to aid decisions related to healthy living.[38] Incentivizing healthy behavior using rewards and benefits may offset decision bias, where people tend to engage in the behavior to receive the reward.

The function of feedback has been widely used as means to communicate these kinds of external benefits. Tim Jackson[39] points out the weakness of such approaches, arguing that when behaviors are limited by external factors such as fun, there was no link between attitude and behavior. Exergame, which uses the fun of playing video games to instigate physical activity, for instance, does not necessarily lead to individuals feeling the need to exercise. Rather, their motivation is more focused on playing the game itself. Moreover, behavior is likely to be dominated by previously rewarded habits until there is an additional incentive to replace them with another behavioral strategy.[40] Once external factors create certain personal benefits, the intervention should move its focus to internal factors such as attitude and norms that eventually serve to activate new behavior, rather than further increasing the external factors.[41] As much as incentives can stimulate a behavior change, behavioral maintenance may require a more intrinsic motivation if it is to be sustained. Edward Deci and Richard Ryan propose that intrinsically motivated behaviors

are based on people's needs to feel competent, self-determined, and autonomous.[42] This is because when people's decision-making is taken away, they may feel relatively less motivated because of being controlled by extrinsic motivations. Extrinsic motivations can always be controlled to some degree, where they act as self-determined regulators. The process of a movement from reliance on external factors to a position of autonomy is referred to as internalization.

Interventions may have a greater impact when behaviors are fully controlled and instigated by products, mediations, or even legislation, without necessarily involving a conscious decision by the users. This contrasts with offering a choice of behavioral change through instrumentality, such as feedback or feedforward. This often involves intelligent products having full delegation of all actions to generate positive behavioral results through silently manipulating people, also known as sustainable by stealth.[43] When an individual considers their behavior to be autonomous, rather than controlled, a more consistent behavior is more likely to take place as far as growing physical activity levels in individuals are concerned.[44]

Despite the lack of sufficient evidence, a number of qualitative studies has suggested that autonomous motivation is essential for maintaining and adhering to physical activity habits.[45] Pedro Teixeira and his colleagues[46] report based on their review, that developing autonomous self-regulation is the purest form of predicting exercise participation and that this is apparent across the range of samples and settings seen in their investigation. They conclude that self-regulating an active behavior such as setting a routine of exercise at home requires a thoroughly structured intervention design to have an effect. They also suggest appropriate duration of research to evaluate its impact. The intervention should be designed to encourage behavioral change by giving information that increases self-efficacy and drive to control the behavior change. Scripted functions create spontaneous occurrences for internalizing the changed behavior (self-regulation).

Design-Led Intervention for Active Behavior

There is insufficient evidence to support claims that excessive screen watching directly harms child development. There is evidence that watching too much screen will eventually contribute to prolonged sedentary behavior which may affect sleep, family interaction, and physical activities.[47] Television has been recorded as representing the largest source of screen-based media exposure for most children.[48] At the same time, there has been an increase in urbanization, changes in lifestyle, and changes in nutrition across various demographics.[49] Some of these factors include changes in dietary choices because of fast-food trends, sedentary living, television viewing, use of media technologies, and lack of physical activity.[50] There is an increase in the number of studies that demonstrate a significant relationship between sedentary behavior, inadequate physical activity, and a high risk of developing chronic diseases.[51] Aric Sigman argues that not only is screen time sedentary behavior, but it is also associated with increased weight gain in children.[52] This emphasizes the need for measures to replace screen time with more active behaviors.

35 Debra Lilley, "Design for Sustainable Behaviour: Strategies and Perceptions," *Design Studies* 30, no. 6 (2009): 705, https://doi.org/10.1016/j.destud.2009.05.001.

36 Anthony Giddens, *The Constitution of Society: Outline of the Theory of Structuration* (Berkeley: University of California Press, 1984), 4–5.

37 Frederick J. Zimmerman, "Using Behavioral Economics to Promote Physical Activity," *Preventive Medicine* 49, no. 4 (2009): 290, https://doi.org/10.1016/j.ypmed.2009.07.008.

38 Colin F. Camerer, George Loewenstein, and Matthew Rabin, eds., *Advances in Behavioral Economics* (Princeton: Princeton University Press, 2004), 10–11.

39 Tim Jackson, *Motivating Sustainable Consumption: A Review of Evidence on Consumer Behaviour and Behavioural Change* (Guildford, UK: Sustainable Development Research Network, 2005), 93.

40 Lucas Carden and Wendy Wood, "Habit Formation and Change," *Current Opinion in Behavioral Sciences* 20 (April 2018): 119, https://doi.org/10.1016/j.cobeha.2017.12.009.

41 Paul C. Stern, "Information, Incentives, and Proenvironmental Consumer Behavior," *Journal of Consumer Policy* 22, no. 4 (1999): 474, https://doi.org/10.1023/A:1006211709570.
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42 Edward L. Deci and Richard M. Ryan, "The 'What' and 'Why' of Goal Pursuits: Human Needs and the Self-Determination of Behavior," *Psychological Inquiry* 11, no. 4 (2000): 236–37, https://doi.org/10.1207/s15327965pli1104_01.

43 Debra Lilley, Vicky A. Lofthouse, and Tracy A. Bhamra, "Towards Instinctive Sustainable Product Use" (paper, presented at 2nd International Conference in Sustainability, Creating the Culture, Aberdeen, UK, November 2–4, 2005), https://hdl.handle.net/2134/1013.

44 Martyn Standage and Richard M. Ryan, "Self-Determination Theory and Exercise Motivation: Facilitating Self-Regulatory Processes to Support and Maintain Health and Well-Being," in *Advances in Motivation in Sport and Exercise*, 3rd ed., ed. Glyn C. Roberts and Darren C. Treasure (Champaign, IL: Human Kinetics, 2012), 233–70, https://doi.org/10.5040/9781492595182.ch-007.

45 Simon A. Brandon-Lai, Daniel C. Funk, and Jeremy S. Jordan, "The Stage-Based Development of Behavioral Regulation within the Context of Physically Active Leisure," *Journal of Leisure Research* 47, no. 4 (2015): 415, https://doi.org/10.1080/00222216.2015.11950368; Florence-Emilie

Given this association between television time and behavior and the role the home plays in influencing these behaviors, modifications of the domestic setting could facilitate behavior change.[53] Yet, we have found the literature inattentive to the home context. A number of studies has been undertaken where there have been attempts to reduce screen time at home. These have been done in a variety of ways: behavioral counselling,[54] removing television from children's bedrooms,[55] and exergaming.[56] The foci of these studies are measures of single factors to initiate a certain behavioral change. These have been stimulating motivation, or using penalties to limit screen usage. A number of factors such as immediate rewards may motivate some individuals to engage in more exercise. Support for the behavioral economics theory that financial incentives can increase physical activity adherence in the short term, usually for around three months, appears in some systematic reviews.[57] These reviewers highlighted that not enough studies have been undertaken to examine the long-term impact of incentives in regulating physical activity. Others suggest that intervention effects diminish over time.[58]

Combining a number of strategic variables in behavioral research is effective. The variables in combination may include such influences of attitudes as motivation, and contextual factors such as monetary incentives, physical capability and constraints, legal penalties, and social norms.[59] Temptation bundling is a term that describes a similar strategy where the intervention involves the coupling of instantly gratifying rewards and long-term goals.[60] This opens up opportunities for the design field where designers can develop interventions that incorporate a combination of behavioral change strategies. Motivation-focused strategies, for example, have been shown to be more effective when combined with a specific function, such as providing instant feedback to encourage more active user engagement in the process of behavioral change.[61]

Researchers have applied such strategies in later studies related to reducing screen-based sedentary behavior. Examples of these include using a mobile application for providing motivational messages and notifications throughout the day to promote exercise (campaign), and additionally providing goal-setting (monitoring) features to track screen time usage.[62] Adults and young adults are the primary users of smart devices and wearable trackers. Researchers have, in recent studies, reported an increase in the use of these intervention components. This has been especially so for those interventions focused on increasing health outcomes. While there is a prima facie case for these technological interventions acting as a stimulus, we argue that the impact of such approaches in longer-term engagement deserves more investigation. In related studies, researchers suggest that multicomponent interventions, such as combining counselling, self-monitoring, social facilitation, and using technological instruments, Fitbit, for example, can significantly reduce sedentary behavior.[63] They also suggest that technological interventions become more effective when facilitated through peer support by pairing parent and child to exercise together,[64] or pairing friends via social media platforms.[65] It may also involve parents and health care providers to cocreate the instigation of physical activity for children with asthma, for example, through blended technological intervention, such as web-based dashboards

Kinnafick, Cecilie Thøgersen-Ntoumani, and Joan L. Duda, "Physical Activity Adoption to Adherence, Lapse, and Dropout: A Self-Determination Theory Perspective," *Qualitative Health Research* 24, no. 5 (2014): 714, https://doi.org/10.1177/1049732314528811.

46 Pedro J. Teixeira et al., "Exercise, Physical Activity, and Self-Determination Theory: A Systematic Review," *International Journal of Behavioral Nutrition and Physical Activity* 9 (2012): article no. 78, p. 22–23, https://doi.org/10.1186/1479-5868-9-78.

47 Russell Viner, Max Davie, and Alison Firth, "The Health Impacts of Screen Time: A Guide for Clinicians and Parents" (report, Royal College of Paediatrics and Child Health, 2019), 4, https://www.rcpch.ac.uk/resources/health-impacts-screen-time-guide-clinicians-parents.

48 Thomas N. Robinson et al., "Screen Media Exposure and Obesity in Children and Adolescents," *Pediatrics* 140, no. Suppl 2 (2017): S98, https://doi.org/10.1542/peds.2016-1758K.

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52 Aric Sigman, "Time for a View on Screen Time," *Archives of Disease in Childhood* 97,

and mobile apps.[66] We suggest that future work in this area needs to focus on employing a more theory-based strategy to: (1) evaluate their effectiveness, (2) test with study targets who are relatively less motivated towards increasing physical activity, and (3) increase empirical evidence through longitudinal studies to evaluate the longer-term effects.[67]

Recognizing television viewing as a principal domestic activity and displacing it with light to moderate physical activity appears to be an obvious way to overcome sedentary behavior, and perhaps instigate more active behavior in domestic settings. We identified a limited number of studies on design-led interventions that focused on motivating children to engage in-home physical activity and self-regulating such behaviors. The impact of a therapy-based intervention to regulate physical activity for older demographics with motor disorders has been explored within existing studies.[68] These include the effect of adherence for patients,[69] and the influence on adolescent girls of using digital technologies for healthy lifestyle purposes.[70] The results of these studies support the need to foster interventions that help members of the younger demographics create a regulatory behavior of being active at home. We saw the need for an intervention to serve more than to facilitate a trade-off between physical activity and screen time usage; we saw it as an instrument that would be used to prompt choices that bring a change in existing sedentary routines. There may be several stages where motivational readiness for physical activity may decrease or increase. The instrument may also be used to encourage individuals to choose to make a change to prevent prolonged screen usage.

We found that using a design-led approach is useful for fusing intervention strategies. Such an approach may be used to address users' lack of motivation to engage in physical activity by providing a system that permits users to maintain some level of perceived autonomy. In our research, we used a design-led intervention to instigate a behavior change. We did this through a design script that promotes more responsible use of physical activity and screen usage in the home context.

The Suggested Design-Led Intervention: The Knudgebox

We wanted to create an artifact that would enable children in the home environment to become less sedentary. The primary goal in designing the intervention was scripting the combination of theory-based behavior strategies into an instrument that helps users to reach self-regulation in their exercise behavior and reduce screen time at home. The designed system included two main theory-based functions to stimulate behavioral change. First, it provided the feedback mechanism that showed behavioral information that is related to the amount of physical activity performed by the user and the screen time usage. Another function scripted was the function of screen access control. This may be understood as a contextual factor of behavioral change. Both functions were designed reciprocally to generate an interaction between the user and the system to encourage the intended behavior.

The intervention was named Knudgebox. We gave it to participants to influence the choices they made in regulating the intended behavior. Shin

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53 Rachel G. Tabak et al., "Impact of a Healthy Weight Intervention Embedded within a National Home Visiting Program on the Home Food Environment," *Frontiers in Public Health* 6 (June 2018): article no. 178, p. 5–6, https://doi.org/10.3389/fpubh.2018.00178.
54 Virginia A. Moyer and Margaret Butler, "Gaps in the Evidence for Well-Child Care: A Challenge to Our Profession," *Pediatrics* 114, no. 6 (2004): 1151–21, https://doi.org/10.1542/peds.2004-1076.
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59 Stewart Barr, "Strategies for Sustainability: Citizens and Responsible Environmental Behaviour," *Area* 35, no. 3 (2003): 227–40, https://doi.org/10.1111/1475-4762.00172.
60 Katherine L. Milkman, Julia A. Minson, and Kevin G. M. Volpp, "Holding the Hunger Games Hostage at the Gym: An Evaluation of Temptation Bundling," *Management Science* 60, no. 2 (2014): 284, https://doi.org/10.1287/mnsc.2013.1784.
61 Sara Backlund et al., "STATIC! The Aesthetics of Energy in Everyday Things" (paper, presented at the Design Research Society Wonderground International Conference 2006, Lisbon, Portugal, November 1–4, 2006), 12, available at http://www.redstrom.se/johan/papers/wonderstatic.pdf.
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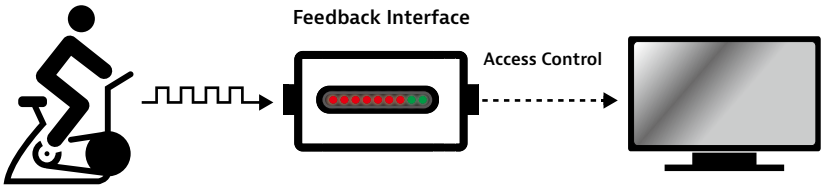

Figure 1
System diagram of the Knudgebox. © 2022 Hyunjae Daniel Shin, Florence Nwankwo, Amin Al-Habaibeh.

and Bull emphasize this as a dimension of empowerment where the user is enabled by using the system to build a volitional sense of taking responsibility for their choices, and increasing feelings of self-worth.[71] Proponents of the nudge theory take the position that little prompts can alter behavior while giving an individual the freedom to maintain a feeling of being in control of their decisions. We designed the intervention to provide individuals with choices that they make simultaneously in relation to their exercise routine and screen.

Figure 1 shows the system diagram of the Knudgebox prototype used in this study. The system is comprised of three components with descriptions of its function given below.

Exercise bike: Each participant was provided with a foldable exercise bike which was wire connected to the feedback interface unit. When participants pedaled the bike, a signal was transferred to the feedback interface unit that converted the exercise amount to display through an LED bar gauge indicator. In the initial stage of the prototype development, we considered different options for exercise devices such as punching bags, dancing mats, and foldable exercise bikes. After trials of testing, we concluded that the bike produced the most stable input data that could accurately measure the exercise amount.

Feedback interface unit: The unit captured a signal from the exercise bike (pedal revolution), and also received a signal from the screen device (screen time usage). An LED bar indicated the behavioral information: the bar length increased when the user pedaled the bike, and the bar length decreased when the user used the screen. The fluctuation of the LED bar could happen, meaning that the user could use the bike and watch the television simultaneously.

Screen unit: This was a television set connected to the feedback interface unit. Participants could use the television set to watch television. They could also connect a game console to the television set to play video games, something most of them did from time to time.

We designed the Knudgebox to allow access to screen usage only after participants had added an exercise amount to the system. This could be viewed as a screen credit by participants. The tools for nudging included default options of filling up the LED bar, or not, as shown in Figure 1. The LED bar was designed to increase when a user was exercising and decrease when the screen device was in use. A user gets on the bike ready for exercise, for instance, and as they continue to exercise, the LED bar continues to increase until they finish their exercise. The LED bar will begin to decrease when the screen

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64 Vijay A. Mittal, Joseph Firth, and David Kimhy, "Combating the Dangers of Sedentary Activity on Child and Adolescent Mental Health During the Time of COVID-19," *Journal of the American Academy of Child and Adolescent Psychiatry* 59, no. 11 (2020): 1197–98, https://doi.org/10.1016/j.jaac.2020.08.003; Pipsa P. A. Tuominen et al., "Relationship between Mothers' Enjoyment and Sedentary Behavior and Physical Activity of Mother-Child Dyads Using a Movement-to-Music Video Program: A Secondary Analysis of a Randomized Controlled Trial," *BMC Public Health* 20, no. 1 (2020): article no. 1659, https://doi.org/10.1186/s12889-020-09773-4.

65 Kate Parker et al., "Understanding Australian Adolescent Girls' Use of Digital Technologies for Healthy Lifestyle Purposes: A Mixed-Methods Study," *BMC Public Health* 22, no. 1 (2022): article no. 1464, https://doi.org/10.1186/s12889-022-13869-4.

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66 Annette Brons et al., "Translating Promoting Factors and Behavior Change Principles into a Blended and Technology-Supported Intervention to Stimulate Physical Activity in Children with Asthma (Foxfit): Design Study," *JMIR Formative Research* 6, no. 7 (2022): e34121, https://doi.org/10.2196/34121.

67 Noora Aldenaini et al., "Mobile Phone-Based Persuasive Technology for Physical Activity and Sedentary Behavior: A Systematic Review," *Frontiers in Computer Science* 2 (July 2020): article

device is switched on. When the LED bar reaches zero, it will limit its access (no screen), which can be seen as a penalty. When users are confronted with this situation or after a few trials of experiencing the consequences of a no credit situation, the system facilitates a norm activation stage. Participants realize that various choices are available to them to make a behavioral decision. They may choose to continue having access to the screen by exercising further and storing credit for later use. They may choose to stop pedaling and have no access to a screen. They may choose to evaluate the required effort needed to meet their screen usage demand. Screen access is also available while exercising. This means, depending on the intensity of bike pedaling, credit can fluctuate. These contextual cues are communicated and elicit behavior change via a feedback function within the feedback interface unit. We scripted this feedback mechanism to enhance the user's goal-setting behavior using the gauge on the LED bar. We considered this as an element that could facilitate the user making choices on setting daily and weekly exercise and screen time goals, that is, nudging them to regulate behavior. It may be argued that the function of constraining access to television upon reaching zero credit seems paternalistic and does not preserve the choice or liberty on screen access, but our main intention with the intervention was to instigate autonomous self-regulation which still offered choices that they could make to avoid this coercion.

Given these choices, participating children's use of the Knudgebox has three main possible outcomes. The first of these is that children do minimum physical activities to reach their goal of screen time usage. The second is that children disengaged in screen time usage so that they do not perform physical exercise. The third is that children start to have more interest in physical activities and as they gain confidence, activity may replace screen time usage. In the first two options, the two activities are linked. Either of these options will have a better health outcome in the form of more physical activity or that of less screen time usage. The third option is the ideal situation. In this option the desired change of behavior can be achieved.

As stated in the introduction, the recommended physical activity for children aged 5–18 is 60 minutes of moderate to vigorous physical activity. United Kingdom's Office of Communications reports that youth aged between 12–15 spend an average of 2 hours per day on television watching.[72] Through several trials conducted with the pilot study participant, the prototype was calibrated to set the physical activity and screen time ratio of 1:3 (40 minutes of pedaling = 120 minutes [2 hours] of screen time). We chose this output in the major study to support the children meeting their screen time usage recommended guideline of 2 hours. Although 40 minutes of exercise is lower than the 60 minutes suggested by WHO, the intensity of exercise may vary between participants. This meant that the 40 minutes of exercise duration was the best close ratio to meet with average performance. This was also sufficient for the user to perceive it as a full daily exercise amount as it took equivalent effort to fill up the gauge on the LED bar. Also considering that the participants may have engaged in other formal or informal physical activity during school hours, such as walking to school and physical education classes, 40 minutes was a good benchmark.

no. 19, p. 14, https://doi.org/10.3389/fcomp.2020.00019; Rita Orji and Karyn Moffatt, "Persuasive Technology for Health and Wellness: State-of-the-Art and Emerging Trends," *Health Informatics Journal* 24, no. 1 (2018): 79, https://doi.org/10.1177/1460458216650979.

68 Simona Bar-Haim et al., "Effects of Exercise Interventions on Habitual Physical Activity and Sedentary Behavior in Adolescents with Cerebral Palsy," *Pediatric Exercise Science* 31, no. 4 (2019): 416–24, https://doi.org/10.1123/pes.2018-0254.

69 Saskia M. Kelders et al., "Persuasive System Design Does Matter: A Systematic Review of Adherence to Web-Based Interventions," *Journal of Medical Internet Research* 14, no. 6 (2012): e152, https://doi.org/10.2196/jmir.2104.

70 Parker et al., "Understanding Australian Adolescent Girls' Use of Digital Technologies."
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71 Shin and Bull, "Three Dimensions of Design," 4–5.
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72 Ofcom UK, "Children and Parents: Media Use and Attitudes Report 2017" (research report, Ofcom, November 29, 2017), 3, https://www.ofcom.org.uk/research-and-data/media-literacy-research/childrens/children-parents-2017.

Research Design

The testing of prototypes with users is widely used as one of the primary methods in the field of design. Approaches such as the Home-Usage Test or Home User Test are also used in the marketing field to test the usability of consumer products. In this study, we found that it was important to set a testing period sufficient to evaluate the internalization of intended behavior. We found little evidence in the literature to explain what an appropriate testing period might be, but in a study that explored how habits are formed in the real-world, researchers observed 92 individuals for 12 weeks. They conclude that automaticity of behavior took participants an average of 66 days to develop.[73] They stress that if the study were to be replicated, the plateau of automaticity would vary between 18 and 254 days. With this consideration of the required study length and with a limited number of available Knudgebox prototypes, we set the duration of the study as a minimum of 12 weeks. It took 11 months in total.

Table 1 details the stages of data collection. In stage 1, before we deployed the prototype, we spent 7 days capturing the baseline data of average screen time using an off-the-shelf energy metering device. The metering device was set to capture the screen time usage by measuring the energy consumption of designated television, which was later converted to their daily average. We used this data to evaluate the changes in screen time during the intervention period. We conducted a short interview in Week 1 (stage 2). We did this to understand each participant's expectation of behavior change throughout the study and to understand their general home activities that were related to sedentary behavior. We also installed the system and gave the participants safety guidance. As we installed the system, we made it clear to parents and other household members the necessity of avoiding any disruption in the data collection. We stipulated that the designated screen device and the exercise

73 Phillippa Lally et al., "How Are Habits Formed: Modelling Habit Formation in the Real World," *European Journal of Social Psychology* 40, no. 6 (2010): 1002–3, https://doi.org/10.1002/ejsp.674.

Table 1 **Method detail shown by stages.**

Stage	Purpose	Methods	Data collection point
Stage 1	Baseline measure for averaging screen time	Meter device	Week 0
Stage 2	Deployment of Knudgebox system	Pre-intervention interview	Week 1
Stage 3	Assessment of motivational influence on self-regulation	Survey	Week 5
Stage 4	Assessment of motivational influence on self-regulation	Survey	Week 10
Stage 5	End of study interview	Interview	Week 12
Stage 6	Post-intervention behavior assessment	Survey	Week 14

bike were to be used only by the study participant. In doing this, we limited the use of other media-related devices during the intervention period. From Weeks 1 to 14, all participants were left with the Knudgebox system that recorded their behavioral data of physical activity input and screen time usage in units of seconds. These data were recorded on a secure digital card that was enclosed in the Knudgebox housing unit and, therefore, not accessible by any participants.

To monitor all participants' continuous participation, we sent a series of surveys in Weeks 5 (stage 3) and 10 (stage 4). This also allowed us to capture how their motivations were affecting the self-regulation of new behavior. The criteria we used for the selection of questions were based on how scripted functions affected their motivation towards the self-regulation process. We were assessing their perceived ability, norm activation, and how the penalty function affected their subsequent actions and determinants to continue carrying the intended behavior.

Stage 5 was the most crucial part of the main study when we interviewed the parents and the actors (children) to understand their determinants of behavior. We formulated a set of questions based on their pre-intervention interview and Week 5 and 10 surveys, along with the behavioral data they generated during the previous 12 weeks. All interviews were transcribed verbatim and we imported these into NVivo to facilitate a thematic analysis.[74] Using this analysis, we constructed a set of themes with relevant codes accounting for how the intervention had affected their motivational influences throughout the participation period. Using these codes and accounting comments, we later cross-referenced them with the stages 3 and 4 survey data, as well as their behavioral data to assess the validity of their interview responses.

In the final stage, stage 6, we conducted a short survey. This was taken two weeks after the conclusion of the intervention to evaluate any changes in behavior.

Before the first deployment, we carried out a three-week pilot study to assess the viability and practicality of the data collection process and made minor changes to the research design.

Recruitment of Participants

As stated in a report from the United Kingdom's Office of Communications, 90% of those surveyed in the 12–15 age group watch television for around 14.5 hours a week.[75] The United Kingdom's National Health Service further reports that meeting physical activity guidelines declines with age; this is evident in the observation made by researchers from the Office of Communications that this age group had shown a considerable decline in meeting the guidelines.[76] A more recent survey shows that 40% of parents state that their children spend an average of 6 hours a day watching television, that 84% of these parents are concerned about their children's screen time usage, and that 76% of them report that their children are inactive because of their screen time-related behaviors.[77] We have used these findings to guide our selection of the study population which targets children between 11 and 15 years of age. The process we used to conduct the recruitment involved selecting samples from the aforementioned survey.[78] We targeted parents who showed some degree of concern over

74 Virginia Braun and Victoria Clarke, "Using Thematic Analysis in Psychology," *Qualitative Research in Psychology* 3, no. 2 (2006): 77–101, https://doi.org/10.1191/1478088706qp063oa.

75 Ofcom UK, "Children and Parents."

76 Shaun Scholes, *Health Survey for England 2015 Physical Activity in Children* (Leeds: NHS Digital, 2016), http://healthsurvey.hscic.gov.uk/media/37752/hse2015-child-phy-act.pdf.

77 Florence Nwankwo et al., "Evaluation of Children's Screen Viewing Time and Parental Role in Household Context," *Global Pediatric Health* 6 (January–December 2019): 4, https://doi.org/10.1177/2333794x19878062.

78 Ibid.

their children's screen time and their increased sedentary behavior. The study sample was classed as a vulnerable group. This meant that permission for them to participate required written consent from their parents or guardians. We recruited 20 households in the United Kingdom. We did this on the basis that parents had already expressed concern over their children's sedentary behavior and excessive screen time. Drawing from 20 households we ended up with 10 boys and 10 girls. The participants had no medical conditions that would affect their participation. They all had ready access to screen devices. We did not offer compensation of any type to avoid any bias in the data collection. The Joint Inter-College Ethics Committee granted ethical clearance for this study.

Findings

We accept that there is a number of subjective variables that affect behavioral determinants. Nonetheless, we have identified notable effects in our analysis of the study samples. Drawing on both our qualitative and quantitative behavioral data, we can see that their attempts at self-regulating new behavior were affected by the Knudgebox.

Data on Behavioral Change

The participants' average screen time before intervention was 9.3 hours per day, which can be seen as an unsustainable behavior. This is higher than the average reported in previous studies. We note that this is not a true reading of screen time usage as the meter device counted the time when the television was on even when the participants were not watching it. By the end of the intervention study, all the participants' screen time usage had a significant reduction. The resulting screen time was an average of 45 minutes a day. Even the observed highest average daily screen time in one households — 93 minutes — still complies with the WHO guidance.

There were notable changes to self-regulation of exercise at home. The total average for physical activity across the participants was 22 minutes per day. This indicates, to some extent, an effect of the design-led intervention. We recorded the highest average physical activity as 80 minutes a day. We recorded that the average attempt at exercise per week was 3 days.

Has the User's Screen Time Behavior Changed as a Result of the Design-Led Intervention?

As seen in Figure 2, there was a 92% screen time reduction rate across all households at the end of the study period. From the pre-intervention interview we see that people underestimate how much time they spend on their screen devices, with 5 out of the 20 participants underestimating their screen time. One particular household underestimated their average daily screen time by 7 hours. Our intention with this intervention was not only to make participants more aware of screen time usage but also to make this more visible. We anticipated that making participants more conscious of their screen time usage would lead to a behavior change, such as switching off the television when it was not in use. We observed an attitudinal change toward screen time usage in participants, for example:

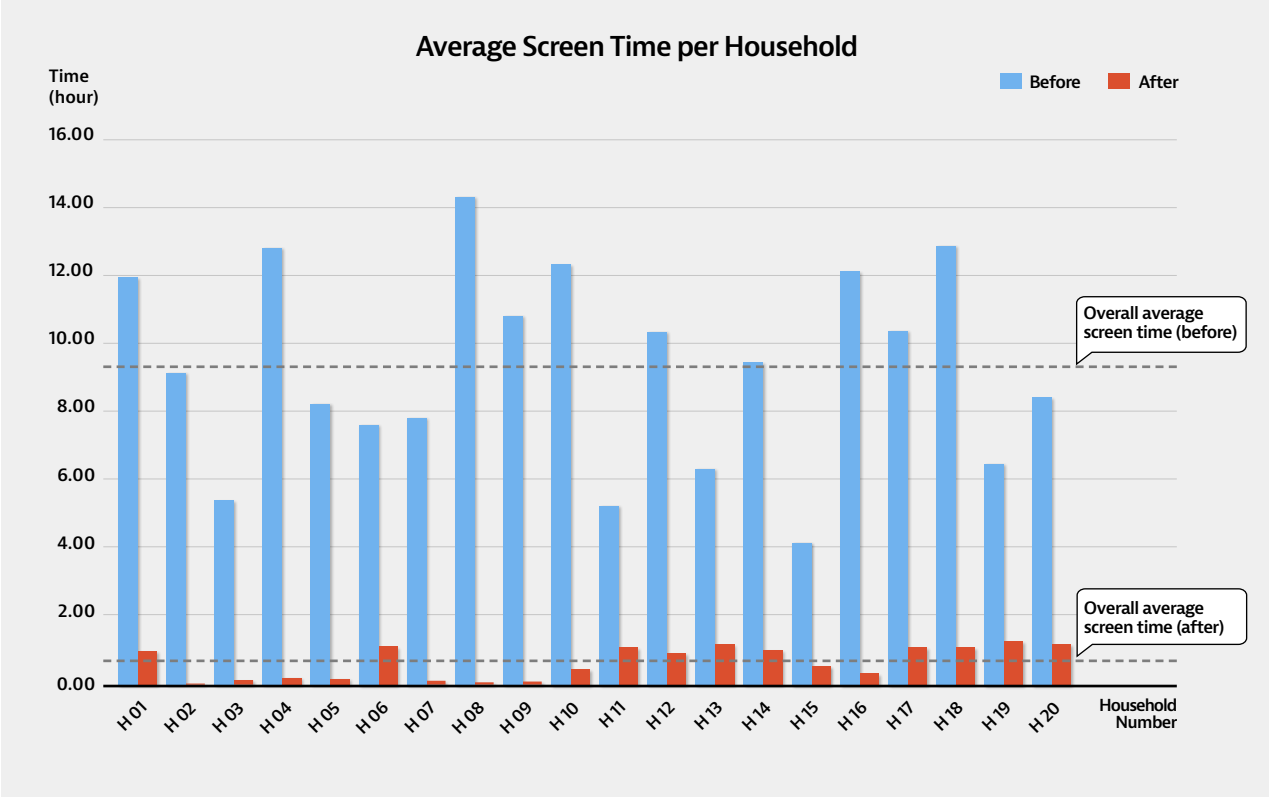

Figure 2
Average screen time (watching television and playing games) recorded before and after the intervention for all participants. © 2022 Hyunjae Daniel Shin, Florence Nwankwo, Amin Al-Habaibeh.

> "Honestly, I think I am better at managing my time now, especially gaming time. I and my mum also work better and fight less. But I definitely see her point now because it was kind of difficult to think that I had to work for my screen time." (Participant 12)

We argue that the interplay between the feedback and feedforward, and the goal-setting function scripted on the Knudgebox, have generated such changes in attitude. The intervention has allowed participants to challenge their previous behavior and to take ownership of their new behavior. They have reconsidered screen time usage as "taking it from physical activity" instead of taking it for granted. Participants were enabled by the design-led intervention to rethink the time they spent on their devices and they were encouraged to disconnect sometimes. This occurred even when there was no recorded exercise activity. Regardless of how much time they spent on screens or how much exercise they performed, participants used the feedback interface unit in making choices to behave more responsibly, while also taking the options to create goals or make plans to limit their screen time usage. Participants showed a sense of personal agency associated with an increase in motivation and interest. In our observations we noted that the participants initiated their own goals; we presumed that they felt more determined to change their behavior:

> "I went on the bike most days straight after I came home because I knew I needed to get that out of the way before watching television." (Participant 17)

Not all participants showed the same effect. A few participants showed a reduction in screen time while at the same time having the lowest average physical activity. This does not necessarily mean the intervention was ineffective, but it indicates that participants may have spent those reductions of screen time usage on other social activities at home. Some of these participants were engaged in other types of behaviors, such as interacting with family members or participating in other activities that did not involve screens. This indicates that the feedback mechanism can be aligned with opportunities. The feedback mechanism can also be aligned with challenges that adversely affect behavior. One participant, for instance, felt that the activity was too difficult for them. They struggled to set goals and expressed a lack of motivation. This participant constantly decided to abort their activity mid-way. This participant perceived the feedback as a task-motivation process, which resulted in feedback discrepancy. Their decision to discontinue the activity after receiving feedback was a way of dealing with feedback that had an adverse effect on their behavior. We observed that when the participants received negative feedback there was a change in attitude leading to a shift in choice of activity. This shows that in some cases, visual feedback discouraged them from engaging in the intervention rather than encouraging them. This is not always the effect of negative feedback. Daniel Ilgen and Cori Davis suggest that challenges that result in negative feedback may also lead to purposive thinking.[79]

We found that participants' attempts to achieve their goals related to physical activity involved various techniques. In our study, we took into account the potential unintended consequences that could result when access to a screen becomes a reward for performing physical activity. We homed in on the notion that regulation was not merely measured by the consistency of the behavior engagement over time, but also by the user's ability to resist going back to the old routine. This would imply that they are regulating the new behavior.

Using interviews, we examined how users employed both the self-regulatory strategies of motivation and volition, as well as other supporting interventions such as those seen through encouragement from family members and friends. We found that some participants did not require any strong motivation or volition but only needed small nudges such as setting a reminder to exercise after school hours. Given this, we suggest that behavioral change should not be an attempt only to engage in the stipulated behavior and that repeated actions must be reinforced by the intervention to build the behavior into a regulation. Here, we define behavioral regulation as the ability of a participant to control and manage their new behavior. We found that participants seeking to attain self-regulation used a variety of strategies to reach this goal rather than those scripted by design. We consider this to be them making autonomous decisions. From literature cited above, we note that internalization is the final phase of the change process. In this phase people no longer evaluate the relative costs of their behavior. This is where they can regulate and sustain their behavior in the absence of cues.

Responsive and Inert Groups

All participants demonstrated changes in patterns of behavior to varying degrees. Given this, it was important to group the participants according to these

79 Daniel R. Ilgen and Cori A. Davis, "Bearing Bad News: Reactions to Negative Performance Feedback," *Applied Psychology* 49, no. 3 (2000): 560, https://doi.org/10.1111/1464-0597.00031.

patterns. This enabled us to understand further how self-regulation occurred or where it was lacking. We developed two different behavioral archetypes which we designated as responsive and inert groups. We used three behavioral variables: average exercise duration for each session, average exercise count per day, and screen time reduction percentage. Using the numerical computing software MATLAB, we computed the data obtained and normalized them by scaling the variables to have values between 0 and 1. To classify the participants into two equal groups we calculated an overall mean to give a threshold score. It is important to note that our aim was not to have a threshold line to identify the group but, rather, to review the patterns in each group to understand what impacted their behavior determinants.

The responsive group engaged the most with the intervention. They showed an average of 33 minutes per day of physical activity as seen in Figure 3. We observed some fluctuations over the weeks. A few participants showed high engagement, but all participants managed to perform at least 20 minutes of daily exercise. This group maintained a similar amount of self-regulation from the initiation to the end of the study. An interesting feature of this group's behavior was that of conserving the screen time credits. Figure 3 graphs the daily average difference between physical activity and screen time across 12 weeks of participation, illustrating their conserving behavior. These participants tend to maintain their daily exercise regulation to avoid the feeling of frustration associated with losing screen time. This could have been difficult to manage without the existence of the feedback

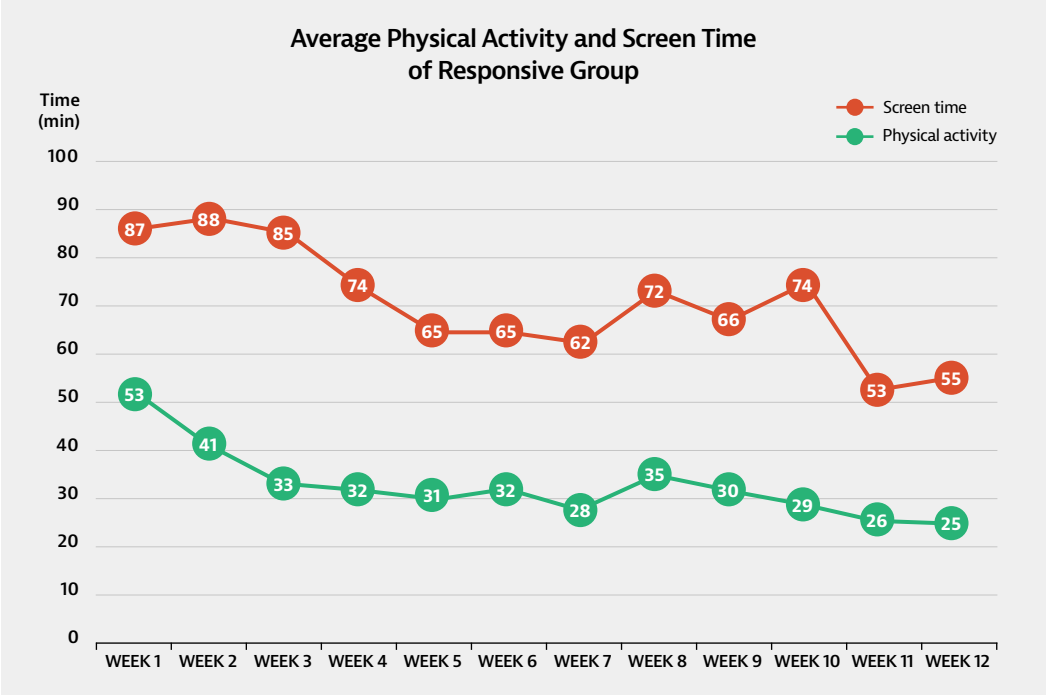

Figure 3
Daily average of physical activity and screen time for the Responsive Group. © 2022 Hyunjae Daniel Shin, Florence Nwankwo, Amin Al-Habaibeh.

and feedforward. Some participants were focused on the enjoyment and fun of interacting with the feedback interface unit. Their interest increased over time as they experienced the impact of visual feedback and its empowerment. Participants with high engagement had the strongest self-regulation, goal-setting and planning to increase their motivation. It is worth noting that the context of interactions was mostly centered on the usage of screen time rather than exercise monitoring. This meant that their goals were set around avoiding the credit reaching zero, which was no screen time.

> "The trouble is I was trying to do half an hour and it doesn't give me enough time on the screen, so I needed to do more. Thirty minutes gave me roughly an hour and that was kind of annoying, so I stuck to doing 30 minutes all the time or just slightly over just to make sure I exercised and that was better than doing it because of the screen time I can get." (Participant 4)

The inert group had an overall average of 11 minutes of physical activity per day. This is one third of the average shown by the other group. This duration of physical activity can still be subjectively perceived as an active routine. Some of the participants' daily average physical activity time reached 25 minutes (Participant 11) and 19 minutes (Participant 3), which were closer to the average of the responsive group than the rest. Still, their overall behavior indicated a low engagement in physical activity over the course of the study. This pattern was not the same with all participants. As illustrated in Figure 4, one participant attempted to increase their daily physical activity. This peaked

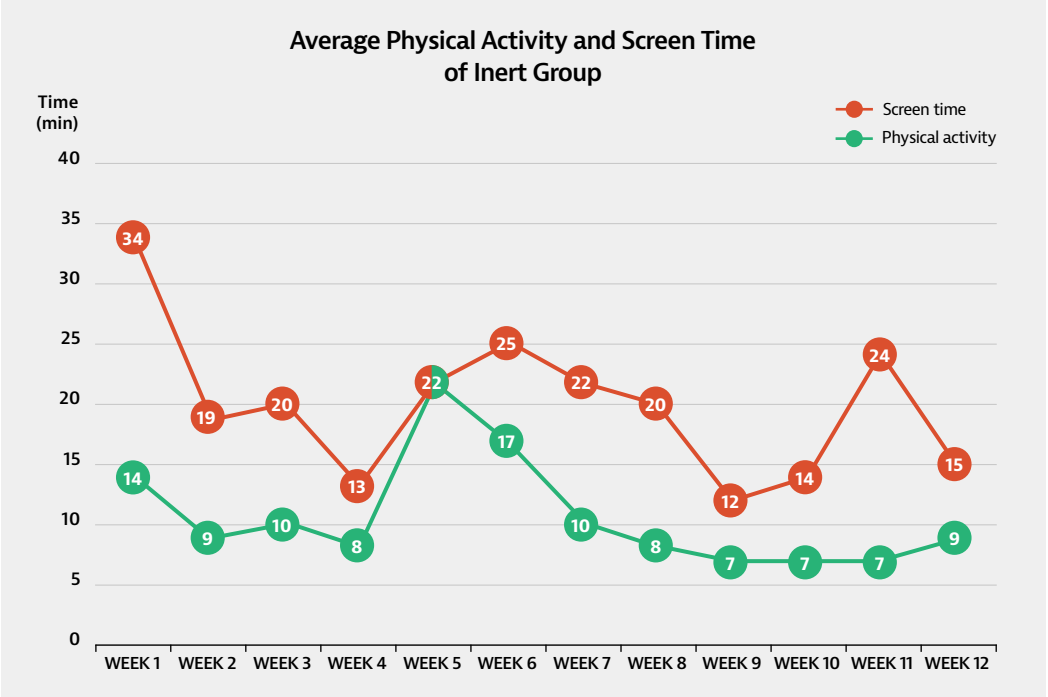

Figure 4
Daily average physical activity and screen time for the Inert group. © 2022 Hyunjae Daniel Shin, Florence Nwankwo, Amin Al-Habaibeh.

80 **Schwartz, "Normative Influences on Altruism."**

at 114 minutes in Week 5 and 90 minutes in the following week. This had an impact on the average graph at Weeks 5 and 6, but their overall engagement stayed low towards the end of the study.

The inert group typically showed resistance to the intervention and they struggled to build any direct motivation from it. This is evidenced in the Weeks 5 and 10 surveys. Our reading of literature on the theory of behavioral change suggests to us that, after the initial adoption of new behavior and where the actual result does not reflect the individual's expected value, is the point where the individual would relapse.[80] A notable finding from this group is the narrow marginal difference between the average screen time usage and physical activity. This is much smaller than the responsive group. This is an indication of their lack of engagement with the program and frequently being faced with no access to screen time usage throughout the study. Although they showed several peaks depicting their attempts at regulating new behavior, their overall tendency declined to an average of 11 minutes of physical activity and 20 minutes of screen time usage. It stood in stark contrast with the responsive group's overall average of 33 minutes of physical activity and 70 minutes of screen time usage per day.

We argue that aiming to do a small amount of exercise is better than people feeling stressed over physical inactivity. As participants in the inert group discussed their lack of motivation in relation to external influences, they also expressed a lack of social support as contributing to their amotivation. Participants in this group seldom mentioned health benefits. This suggests that any discourse attempting to motivate this group will need to encompass additional benefits other than the long-term health benefits associated with exercising, for example, incentive. At the same time a lack of engagement with the Knudgebox does not necessarily translate as ineffective since the reduction of screen time usage has occurred throughout the intervention period. One participant, for example, reported that they found alternative behaviors such as playing outside, leaving early to walk to school, and interacting with other social activities as a replacement for their previous screen-based sedentary behavior.

Maximizing the information the user puts into the feedback interface unit generates the optimum visual feedback needed to change their behavior. In the responsive group, the user begins to understand the impact of their behavior through the function of the feedback and feedforward provided. The interdependency of goal-setting and regulatory motivation can affect individuals. The participants in the inert group, for example, may have felt less empowered and visual feedback may have had minimal impact. This resulted in decision-making capability being limited. In the responsive group, the engagement is characterized by the shared effects of both visual feedback and empowerment. This resulted in the user being fully involved in their decision-making. We categorized the various factors affecting these decisions as being either a challenge or an opportunity. One participant, for example, was motivated to engage in exercise and used the visual feedback as an indication to increase their daily exercise. In another case, a participant was equally interested in exercising, but struggled with the incremental speed of the LED bar; this impacted their motivation and autonomy and they

identified it as a challenge. In addition, participants perceived features such as the relentless application of the penalty of cutting off screen time to be more of a deterrent to the use of the compliance-oriented script of the intervention. For a behavior change intervention to be successful, we argue that behavior change strategies such as goal-setting, feedback and feedforward must be incorporated with the design of the intervention. These functions should be tailored to the targeted participants based on their characteristics and interrelated to facilitate the process of self-regulation with greater self-determination.

Discussion

We undertook this study to investigate how impactful the design-led intervention would be in facilitating the self-regulation of active behavior at home. Given our findings, we concluded that the participants' screen time usage was significantly reduced, and the instigation of exercise behavior has contributed to a change in the home. In our analysis we identified some factors that indicate how users' empowerment vary and fluctuate throughout the stages of behavior change. We found that participants' interaction with the Knudgebox system goes beyond increases in their individual capacity; it also encompasses determinates that could impact continuation of intended behaviors as far as motivation and interest are concerned. User empowerment relates to motivation in different ways, for example, setting goals to increase the chances of personal initiation and persistence to continuously repeat the behavior or being less motivated due to feeling controlled by the functions scripted on the design intervention.

We found that an increase in motivation and interest was associated with participants having a sense of personal agency. When participants initiated their own goals, we observed that they were more likely to change their behavior. We suggest that this was because they felt more determined to change by regulating their behavior of conserving the credit for a more comfortable use of the screen device at a later time.

We also recorded the instigation of new sustainable behaviors. Participants, for example, switched off their television when it was not in use to save credit on the feedback interface unit.

Our analysis shows that a lack of personal agency may be directly associated with self-regulation which leads to low engagement. We observed that some participants felt constrained as a result of having relatively less access to screen time usage than usual. As pointed out in the above section of persuasive technology above, the contextual effect of the feedback and feedforward may act to discourage the intended activity. The lesson we learned from this study is that sometimes behavior change can be authoritarian directed and very often neglect the individual's perception of what they deem to be important. We acknowledge that the use of a design-led approach could be limited if it fails to offer more choice-making opportunities. Our data analysis shows that individual experiences of empowerment may differ, and the stage at which they feel empowered will determine their attitude toward the behavior.

This work contributes to the field of health promotion. Its value lies in its exploration of the interconnection between the autonomy of the Knudgebox user and their motivation to increase physical activity and decrease screen usage time. We have provided reasons for giving individuals greater control and choices. We argue that this can increase their chances of achieving active behavior. The prototype interface we designed was optimized to evaluate its influence on the participants' uptake of scripted strategies related to exercise and screen access. We anticipate that scripting additional choices could potentially address the drawbacks of the limited stimulus. Further, we suggest that speculation of weight loss and sustainability of healthy habits could greatly promote more effective engagement as a longer-term benefit for participants.

This study is not without limitations. We originally designed Knudgebox with the capacity to limit the use of screen time usage using a hand-held device, which limited participants' access to charging. During the pilot study we found that limiting an individual to using a designated charging port on the Knudgebox was very challenging, particularly as alternative ports were widely accessible in their living spaces. Given this, after the pilot study we excluded them. Given that participants could find alternative access to charging led us to consider whether they could find alternative ways to replace screen time usage on the television by using other mobile devices. Even so only a single case was reported. This case was from the inert group and had a low engagement with the intervention. There may have been other cases that were not reported during our data collection. Despite this, we argue that the findings of our study are still valid as television represents the largest source of screen-based media within the home environment.

There is a need to validate further the design-led approach. This would require more advanced methods of assessing its effectiveness. Nonetheless, some of our result lead us to argue that design-led interventions can contribute to addressing the sedentary problem, especially in the home environment.

The key contribution of any intervention studies would be evaluating its effectiveness at both pre- and post-intervention. We found scant empirical evidence in the literature in relation to habit stability. People tend to adopt new behaviors easily, but often fail to maintain these habits over time, especially after the intervention is removed.[81] Two weeks after the intervention finished, we conducted the post-intervention study in the form of a short email survey. Twelve participants reported that they had maintained the daily exercise and another 9 participants said that they had maintained a reduced screen time of around 2 hours a day. This may not be sufficient time for us to claim whether the changed behavior has continued over time, nor its effectiveness in the long term without continued use of the intervention. Our study also has the limitation of using one type of exercise, the bike. This may hinder the regulation of exercise to continue at post-intervention.

It can be argued that the most effective interventions are those that can facilitate individuals to maintain a prolonged active behavior even at post-intervention. The methods we chose and the duration of the study have allowed us to make some claims in relation to the effectiveness of a

81 Jeannet H. Van Houwelingen and W Fred Van Raaij, "The Effect of Goal-Setting and Daily Electronic Feedback on in-Home Energy Use," *Journal of Consumer Research* 16, no. 1 (1989): 103, https://doi.org/10.1086/209197.

design-led intervention developed to facilitate a process of self-regulating an active behavior at home. We have demonstrated that feedback and feedforward play an important role in facilitating a continuous interplay between motivation and goal-setting that can be applied in any form of physical exercise. We have also demonstrated that the Knudgebox is an appropriate nudge system for participants to develop this type of autonomy. Participants engaging with this system are also able to experience spontaneous occurrences that lead to the internalization of their changed behavior.

We collected the data before Covid-19 broke out. We assume there are many scholarly articles concerning the increased screen time during the Covid-19 period. We anticipate a follow-up study that uses a similar program of intervention would add to the findings of this study. Future research could make a further contribution by increasing the population sample to include a broader demographic with the view that a comparative study on cultural and regional differences would add more value to our findings. Conducting a comparative study between controlled and experimental groups would enhance the evaluation of intervention effectiveness. This would also test different approaches to design-led strategies through a comprehensive longitudinal study. Other researchers suggest that to improve the health outcomes of children, it will be crucial to create sustained lifestyle patterns of regular physical activity that will continue into adulthood.[82] Given the likelihood that the targeted sample group will eventually be more exposed to screen time via hand-held devices, a service-oriented or app-based design intervention should be regarded as a priority for future research.

While we acknowledge that there are limitations in the study, we are offering a basis for future studies to be undertaken in the field. Such studies may be used to explore similar types of interventions as ours. The post-Covid-19 environment suggests an urgency for such interventions in targeted behavior. The aim of such programs of intervention is the development of sustainable practices that can take place in a variety of situations. Developers of future interventions aiming to modify behavior in various domains should consider merging the knowledge of designers, social scientists, behavioral psychologists, and health professionals.

Conclusion

Obesity and sedentary behavior of children is a global issue. Understanding how children's exercise behavior can be improved is also a global issue. In this paper we add to the effort by offering an example of how product designers may contribute to improving children's behavior and their disposition towards exercising. The intervention of the Knudgebox described in our study has been designed to change the contextual cues that trigger new behavior. We have done this with the expectation that repetition of the behaviors will achieve self-regulation. In our design-led intervention we have helped to build an exercise routine that will improve health in the home environment. Our argument is that emphasizing the interaction of design elements such as feedback and feedforward functions can empower the user to sustain the changed behavior.

82 Vitor P. Lopes et al., "Habitual Physical Activity Levels in Childhood and Adolescence Assessed with Accelerometry," *Journal of Sports Medicine and Physical Fitness* 47, no. 2 (2007): 217–22, available at https://pubmed.ncbi.nlm.nih.gov/17557062/.

Other researchers tend to focus on physical activity interventions centered on the workplace, school, or outdoor activity. Such researchers aim to increase participants' daily recommended amounts of physical activity. We selected the home environment. We note that the home environment is filled with today's mundane socio-technical systems of everyday life. These are primarily dependent upon screens. Despite the acknowledged limitations of our study, we introduce a novel approach that induces new behaviors resulting in self-regulation that bring a positive impact by reducing sedentary behavior. We applied theories drawn from the literature to the design of a prototype. Our aim is to provide a process in which an individual may self-regulate their changed behavior. The methods we employed in this study, we argue, should be taken as a key contribution to the field. In doing so we have demonstrated the feasibility of real-time measurement. We did this by using mixed methods to investigate both internal and external motivation in an intervention period of 12 weeks. An outcome that we note is how the role of design can support or hinder the process of internalizing new behavior. We suggest that other researchers can use our process in their own evaluation of any design-led intervention with a similar goal of behavioral change. We draw on the critique of others in regard to the complexities involved in changing behavior, the mechanism through which behavior change interventions can modify and sustain behavior.[83] In this study, we extend knowledge related to behavior change by providing evidence of how design-led intervention can be effective in identifying the problem of inactivity and excess screen usage. Further, we provide evidence that Knudgebox may be used by children as they develop the autonomy to manage and regulate newly adopted behaviors.

83 Lauren E. Connell et al., "Links between Behavior Change Techniques and Mechanisms of Action: An Expert Consensus Study," *Annals of Behavioral Medicine* 53, no. 8 (2019): 708–20, https://doi.org/10.1093/abm/kay082; Pramod Ratnakar Khadilkar and Philip Cash, "Understanding Behavioural Design: Barriers and Enablers," *Journal of Engineering Design* 31, no. 10 (2020): 508–29, https://doi.org/10.1080/09544828.2020.1836611.

Declaration of Interests

There are no conflicts of interest involved in this article.

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