Available online at www.sciencedirect.com

ScienceDirect

Current Opinion in Behavioral Sciences

Habit formation and change

Lucas Carden[1] and Wendy Wood[1,2]

This review highlights emerging findings and new directions in research on habit formation and change. We first identify the cognitive, attentional mechanisms that contribute to habit formation. Then we show how habit is transforming the way researchers think about self-control, and how changing habits involves environmental pressures as much as intrapsychic forces. Finally, we describe big data and new technologies that offer novel methods to study habits outside the lab by capturing repeated actions in the natural environments in which they occur.

Addresses
[1] Department of Psychology, University of Southern California, United States
[2] Marshall School of Business, University of Southern California, United States

Corresponding author: Carden, Lucas (lcarden@usc.edu)

Current Opinion in Behavioral Sciences 2018, **20**:117–122

This review comes from a themed issue on **Habits and skills**

Edited by **Barbara Knowlton** and **Jörn Diedrichsen**

For a complete overview see the Issue and the Editorial

Available online 2nd January 2018

https://doi.org/10.1016/j.cobeha.2017.12.009

> *Ninety-nine hundredths or, possibly, nine hundred and ninety-nine thousandths of our activity is purely automatic and habitual, from our rising in the morning to our lying down each night. — William James* [1]

William James never failed to make provocative claims, especially regarding the wide-reaching influence of habit on human behavior. Over a century later, research has moved beyond claims of the importance of habit to identifying the psychological mechanisms that drive habit formation and change.

Habits form as people pursue goals in daily life. When repeatedly performing a behavior in a particular context, people develop implicit associations in memory between contexts and responses. Instrumental and Hebbian learning processes are involved [2••].

As people repeat a behavior in a stable context, their intentions and goals to perform it gradually become less influential guides, whereas habits increase in influence [3,4]. Although theories of habit differ in details, all recognize this shift from goal-directed to habitual behavior through repeated learning [2••,5,6]. Ironically, people's lay theories of habit do not recognize this shift in action control (for review, see [7]). People commonly use volitional, goal-directed explanations for why they perform habits, even when intentions and goals fail to guide actual performance [8].

Psychology has in recent years focused on the flexible responses generated by the nonconscious activation of goals and attitudes [9]. In contrast, habit cuing involves relatively fixed response patterns. Habits are slow to develop and change in comparison to other implicit processes such as Pavlovian fear conditioning [10]. To this end, habits are a challenging construct to measure and manipulate in the lab. Yet new technologies are providing novel insights into habits in the lab and everyday contexts (e.g. [11]).

In this paper, we highlight emerging findings and new directions in research on habit. First, we briefly review new research showing that cognitive, attentional mechanisms appear to be central to instrumental learning of habits. Next, we examine how our understanding of how to change habits is being transformed by research on self-control [12•] and the way environmental, as well as intrapsychic, forces contribute to habit change [13,14]. Finally, we highlight recent studies using innovative technology to study habit formation and change outside the laboratory [15•].

Cognitive processes of habit formation

Attentional mechanisms are important in habit formation, given evidence that instrumental learning guides attention to context cues [16,17]. That is, stimuli that have been rewarded in the past acquire attentional priority over non-rewarded ones [18]. This habit learning phenomenon was demonstrated in experiments in which participants learned to associate, for example, colored circles on a computer screen with monetary rewards. When the task was then reconfigured so that the rewarded stimuli were distractors and participants were to choose new targets, the simple presence of the distractors impeded performance [16]. Through a habit learning pathway (instrumental learning), basic perception and attention systems exhibited performance akin to a habit. People preferentially recognize environmental features associated with past rewards.

Evidence that context cues automatically bring habitual responses to mind comes from a series of studies in which participants practiced a sequential task of making sushi in a computer game (JS Labrecque, W Wood, submitted for publication). With extensive practice, participants were able to quickly report the next step in the sequence when primed with the prior step. The strength of these habit associations in memory determined habit persistence. When participants were especially fast in the priming task, indicating strong habits, their habits persisted even when they wanted to alter the recipe and add a new ingredient.

Habit resistance to change is understandable given context cues that capture attention automatically and given habitual responses that are activated automatically on perception of the cue. Through these basic mechanisms, features of the environment are interwoven into habit formation and change.

Habits and effortless self-control

William James [19] claimed that "the more of the details of our daily life we can hand over to the effortless custody of automatism, the more our higher powers of mind will be set free for their own proper work." By implying that the main benefit of forming habits was to reduce the need for inhibition and self-control, James was prescient about contemporary research on self-control.

Self-control traditionally is a struggle in which one part of ourselves tries to stop another part of ourselves from responding [20]. Inhibitory control was captured most famously in the conflict children experienced between one marshmallow now versus two marshmallows later [21]. In other paradigms, it was represented as a farsighted planner pitted against a myopic doer [22] and in others as a muscle that resisted temptations for a future self [23]. In this struggle, habits were treated as a target of self-control, needing to be inhibited [24]. More recently, research has recognized James's claim, highlighting habit as an automatically activated response that can achieve goals [25].

This shift from habits-as-impediments to habits-as-beneficial is evident in research on trait self-control [26]. We now know that people who score high on such scales do not engage in much effortful inhibition [27]. In fact, they experience less motivational conflict and report less inhibition of temptations in daily life compared with people with low self-control [28,29]. Instead, people high in self-control have weak habits for unhealthy activities (e.g. eating junk food, [30]) and strong habits for healthy activities such as sleep, exercise, and work [12•,31]. One longitudinal study showed that adolescents with high trait self-control had formed meditation habits that better met their goals 3 months after a meditation retreat [12•]. Furthermore, experimental research has shown that positive habits actually protect people from conflicting desires [32].

High trait self-control may thus reflect a kind of situational strategy involving arranging environmental cues to promote beneficial habit formation [33]. People with high control appear to actively avoid situations offering temptations and distractions [34]. A recent longitudinal study directly examined whether experiences of temptations matter more or less than experiences of effortful self-control in the successful attainment of important personal goals [35•]. Over the course of a school semester, college students who experienced fewer temptations in daily life were more likely to achieve their goals than those who experienced more temptations. Critically, experiences of effortful self-control, though depleting, were unrelated to goal attainment. The relationship between temptations and goal attainment was mediated by feelings of depletion, suggesting that the mere presence of temptations lead to experiences of conflicting and depleting desires, whether or not control is engaged.

One implication of this new understanding of self-control is that those who have the foresight to reengineer their home and work environments to reduce temptations will be more likely to achieve their goals. Evidence from studies investigating students' studying strategies indeed suggests that many have this foresight: students who used more situational strategies, such as hiding their cellphone, were more likely to reach their academic goals and not struggle with temptations [36]. Merely manipulating the proximity of desired and undesired foods (e.g. in or out of arms' reach) directly influences healthy eating behavior [37].

Effortless self-control might seem an oxymoron given the traditional characterization of self-control as inhibition. However, we now know that self-control involves a wide range of responses beyond willpower. To be successful, people high in self-control appear to play offense, not defense, by anticipating and avoiding self-control struggles. This strategy, however, does not obviate the need for often inhibiting responses early in the habit formation process. Thus, perhaps inhibitory self-control is needed in the early stages of habit formation and, as time progresses, effortless self-control, or habit, takes over control of behavior. It is likely that people with high self-control may have started playing offense earlier in life and can thus reap the rewards of effortless self-control later in life. To what extent this offensive strategy is conscious or unconscious is a promising area of research to be explored.

Changing habits

Behavior change interventions have been challenged to successfully alter lifestyle behaviors like diet, exercise, environmental sustainability, and financial solvency [14]. For example, the national 5-A-Day-For-Better-Health

fruits and vegetables campaign presented people with information about the pros and cons of health behaviors, attempting to motivate them to change. The campaign successfully increased people's knowledge about what they should do to be healthy, but had limited effect on eating habits [38,39]. Another example comes from highly controlled studies designed to change habits using incentives. These are typically successful in achieving short-term change but fail to maintain change over time, after the incentives are removed (for reviews see, [40,41]).

A habit perspective anticipates limited change in behavior when performance contexts remain stable. Because habits are stored in procedural memory relatively separate from goals and intentions, encountering the same context activates habitual responses, even when newly adopted intentions are strong [42]. The slow pace of habit learning was shown with a variety of health habits, such as exercising, that develop with weeks or months of repetition in stable contexts [43].

New directions in habit change include not only changing beliefs and perceptions but also using cognitive strategies (e.g., reminders) in concert with environmental change strategies.

Implementation intentions, reminders, and rewards

Popular behavior change interventions involve planning and reminders. For example, implementation intentions help people to remember to act on intentions to change behavior. Although earlier reviews indicated the effectiveness of implementation intentions [44], a meta-analysis of over 44 diet studies showed only small behavior change effects during the interventions and negligible long-term effects [45]. Especially for strong antagonistic habits, like unhealthy eating and smoking, implementation intentions have little impact [45,46]. Potentially, implementation intentions could promote habit formation when encouraging repetition in contexts that support the action, like walking in a pedestrian-friendly environment [41]. Interestingly, Turton *et al.*'s meta-analysis revealed more success with food-specific inhibition and attention bias modification training, both of which may target the cognitive mechanisms underlying habit [45].

Reminders and symbolic rewards like trophies are common features of web and smartphone based programs [47]. Although reminders may be effective in the short-term, they can impede habit formation in the long term [47]. Reminders can cause people to deliberate about repeating a behavior, and deliberation sometimes precludes habit formation (Labrecque and Wood, unpub). Deliberation keeps learning processes focused on goals, whereas habit formation arises when goals recede in salience and influence [48].

Web and smartphone applications can also promote app dependence instead of continued repetition of a behavior following app use [49]. Because many apps rely on extrinsic rewards, the apps may crowd out intrinsic motivation to repeat the behavior. Habit change apps that are embedded within a multipurpose technology (e.g. smart watch) can be effective since they may prompt and remind the user to perform a habit (e.g. increasing walking steps) even when the user is performing other actions with the technology (e.g. text messaging).

Although few existing apps focus on repetition of a behavior in a particular context, context-aware technologies are on the horizon (see for review, [50]). These apps and technologies would remind users to perform behaviors when in specific environments, perhaps being triggered by sensors in those environments (e.g. entering the kitchen triggers reminder to drink water). In this way, behavior change apps can facilitate habit formation by connecting specific environmental cues with desired responses.

Changing environments, changing habits

When environments change, the cues activating habits may change also, with the result of disrupting habit performance. Without familiar habit cues, people are forced to make decisions about how to act.

According to the *habit discontinuity* effect, behavior change interventions are more effective during life course changes that disrupt habit cues, such as moving house, having a child, and changing jobs [42,51]. The absence of old cues provides a window of opportunity to make decisions and implement new goals and intentions. In illustration, a recent field experiment with over 800 households, half of which recently relocated, received an informational intervention to promote 25 environmental behaviors [52•]. The intervention was more effective for those who had relocated with the last 3 months (see also [42,53,54]).

A serendipitous example of how environmental disruption changes societal habits occurred with a two day partial London Tube workers strike in February, 2014. From 200 million points of card swipe data, researchers tracked commuters' transportation habits before and after the strike [15•]. The disruption led 5% of commuters to adopt new, more optimal travel-route habits, and these occurred especially in areas where the tube map was inaccurately drawn or commuters could not estimate train speed. The disruption of old cues thus enabled some commuters to discover and form more optimal traveling habits.

Although habits can be disrupted by changes in macro environments or during life transitions, habit performance can also be altered through *choice architecture* or

environmental reengineering interventions that change the structure of everyday decisions [55,56]. Given that habit formation requires repeated responses in a stable context, altering the decision structure may sometimes promote habit formation by making it easier to perform a desired action. Fortunately, conscious decisions to alter the environment, such as dedicating a prominent place for fruits and vegetables on the kitchen counter, might also guide people into *rip currents* [57], potentially leading to a cascade of psychological changes that maintain new behaviors, including identity [58] and physical changes such as weight loss [59]. Rip currents are channels of water that run perpendicular to the beach that can carry someone effortlessly far into the ocean. Analogously, environmental changes, such as manipulating the saliency of a kitchen fruit bowl, can cause people to repeatedly eat fruits, leading to weight loss and new identity attributions (e.g. I am a healthy eater).

Using big data and smart phones to study habits in everyday life

In the past decade, big data and smartphone technologies offer revolutionary new ways to study habits in daily life. These open up fine-grained analysis of the context cues that trigger everyday habits. One example is a smoking cessation study that combined ecological momentary assessment of reported cravings with geo-location mapping (via smartphones) of exposure to point-of-sale tobacco cues [60]. Relapse rates increased with exposure to smoking cues, even when participants were not experiencing cravings. This study suggests that environmental cues direct attention and activate a habitual response in mind, even when people are not experiencing a desire to act.

Big data analyses also reveal important social consequences to seemingly mundane habits, such as how often and where students make purchases on campus [11]. Instead of survey-based methods to assess student retention, researchers modeled students' social networks from the frequency and location of ID card transactions (e.g. campus restaurant, printer services). Students were less likely to drop out in their freshman year if they showed more regularity in their transactions, suggesting greater social integration on campus. An implication is that at-risk students can be identified from such indicators of habitual social integration, and retention interventions can be designed accordingly.

Conclusion and future directions

Habit research has blossomed over the past few years. We are making progress on how basic cognitive mechanisms like attention relate to habit formation [16], how people with high self-control use habits to achieve their goals [12•], and how habit performance is influenced by environmental disruptions [52•]. Additional advances include exciting research on how social interaction habits contribute to intergroup relations [61]. We are also starting to track lay beliefs about habit formation and performance ([62]; for review, see [7]).

Future habit research can mine new technologies to measure the context cues that drive habits. In a unique study in addiction research, smokers took pictures of their favorite smoking environments and brought them into the lab for cue-reactivity tests [63]. Personalized smoking environments led to stronger cravings than generic environments. This method of image analysis holds strong promise for studying habits in controlled settings.

Habits in general stretch researchers' capabilities because they are, at core, interactions between persons and environments. They reflect past implicit learning activated by current context cues. On the one hand, studying habit involves understanding intrapsychic processes such as implicit perceptual, attentional, and memory processes. On the other hand, habit research involves understanding how the world beyond our heads activates habitual responses. Recent research discoveries provide a strong foundation to understand how habits are driven by both the person and environment in these ways.

Conflict of interest statement

Nothing declared.

References and recommended reading

Papers of particular interest, published within the period of review, have been highlighted as:

- • of special interest
- •• of outstanding interest

1. James W: *Talks to Teachers on Psychology and to Students on Some of Life's Ideals*. New York, NY: Holt; 1899.

2. •• Wood W, Rünger D: **Psychology of habit**. *Psychology* 2016, **67**:289-314 http://dx.doi.org/10.1146/annurev-psych-122414-033417.

This paper provides a broad review of the cognitive, motivational, and neurobiological bases of habit. A model is presented of the many ways in which habit interfaces with goal-directed processes.

3. Ouellette JA, Wood W: **Habit and intention in everyday life: the multiple processes by which past behavior predicts future behavior**. *Psychol Bull* 1998, **124**:54-74 http://dx.doi.org/10.1037/0033-2909.124.1.54.

4. Sheeran P, Godin G, Conner M, Germain M: **Paradoxical effects of experience: past behavior both strengthens and weakens the intention-behavior relationship**. *J Assoc Consum Res* 2017.

5. Cushman F, Morris A: **Habitual control of goal selection in humans**. *Proc Natl Acad Sci U S A* 2015, **112**:13817-13822.

6. Gardner B: **A review and analysis of the use of "habit" in understanding, predicting and influencing health-related behaviour**. *Health Psychol Rev* 2015, **9**:277-295 http://dx.doi.org/10.1080/17437199.2013.876238.

7. Wood W: **Habit in personality and social psychology**. *Personal Soc Psychol Rev* 2017:1-15 http://dx.doi.org/10.1177/1088868317720362.

8. Neal DT, Wood W, Labrecque JS, Lally P: **How do habits guide behavior? Perceived and actual triggers of habits in daily life**. *J Exp Soc Psychol* 2012, **48**:492-498 http://dx.doi.org/10.1016/j.jesp.2011.10.011.

9. Weingarten E, Chen Q, McAdams M, Yi J, Hepler J, Albarracín D: **From primed concepts to action: a meta- analysis of the behavioral effects of incidentally presented words**. *Psychol Bull* 2016, **142**:472-497 http://dx.doi.org/10.1037/bul0000030.

10. Amodio DM, Ratner KG: **A memory systems model of implicit social cognition**. *Curr Dir Psychol Sci* 2011, **20**:143-148 http://dx.doi.org/10.1177/0963721411408562.

11. Ram S, Wang Y, Currim F, Currim S: **Using big data for predicting freshmen retention**. *2015 International Conference on Information Systems: Exploring the Information Frontier, ICIS 2015*. Association for Information Systems; 2015.

12. • Galla BM, Duckworth AL: **More than resisting temptation: beneficial habits mediate the relationship between self-control and positive life outcomes**. *J Personal Soc Psychol* 2015, **109**:508-525 http://dx.doi.org/10.1037/pspp0000026.
This paper attempts to reconcile the findings that people with high self-control attain more positive outcomes but do not do so by using effortful self-control. Rather, the researchers posit and find evidence for beneficial habits mediating the relationship between self-control and goal attainment.

13. Marteau TM, Hollands GJ, Fletcher PC: **Changing human behavior to prevent disease: the importance of targeting automatic processes**. *Science* 2012, **337**:1492-1495 http://dx.doi.org/10.1126/science.1226918.

14. Rothman AJ, Gollwitzer PM, Grant AM, Neal DT, Sheeran P, Wood W: **Hale and hearty policies: how psychological science can create and maintain healthy habits**. *Perspect Psychol Sci* 2015, **10**:701-705.

15. • Larcom S, Rauch F, Willems T: **The benefits of forced experimentation: striking evidence from the London underground network**. *Q J Econ* 2017 http://dx.doi.org/10.1093/qje/qjx020.
This paper described an analysis of London commuters' transportation habits before and after a workers' strike. Many commuters exhibited suboptimal traveling routes before the strike and then developed stable, more optimal routes after the strike. Habit and search cost explanations are discussed.

16. Anderson BA: **The attention habit: how reward learning shapes attentional selection**. *Ann N Y Acad Sci* 2016, **1369**:24-39.

17. Le Pelley ME, Mitchell CJ, Beesley T, George DN, Wills AJ: **Attention and associative learning in humans: an integrative review**. *Psychol Bull* 2016, **142**:1111-1140 http://dx.doi.org/10.1037/bul0000064.

18. Luque D, Beesley T, Morris RW, Jack BN, Griffiths O, Whitford TJ, Le Pelley ME: **Goal-directed and habit-like modulations of stimulus processing during reinforcement learning**. *J Neurosci* 2017, **37**:3009-3017.

19. James W: *The Principles of Psychology* . New York, NY: Henry Holt; 1890.

20. Muraven M, Baumeister RF: **Self-regulation and depletion of limited resources: does self-control resemble a muscle?** *Psychol Bull* 2000, **126**:247-259.

21. Mischel W, Shoda Y, Rodriguez ML: **Delay of gratification in children**. *Science* 1989, **244**:933-938 http://dx.doi.org/10.1126/science.2658056.

22. Thaler RH, Shefrin HM: **An economic theory of self-control**. *J Polit Econ* 1981, **89**:392-406.

23. Baumeister RF, Vohs KD, Tice DM: **The strength model of self-control**. *Curr Dir Psychol Sci* 2007, **16**:351-355.

24. Quinn JM, Pascoe A, Wood W, Neal DT: **Can't control yourself? Monitor those bad habits**. *Personal Soc Psychol Bull* 2010, **36**:499-511 http://dx.doi.org/10.1177/0146167209360665.

25. Neal DT, Wood W, Drolet A: **How do people adhere to goals when willpower is low? The profits (and pitfalls) of strong habits**. *J Personal Soc Psychol* 2013, **104**:959-975 http://dx.doi.org/10.1037/a0032626.

26. Tangney JP, Baumeister RF, Boone AL: **High self-control predicts good adjustment, less pathology, better grades, and interpersonal success**. *J Personal* 2004, **72**:271-324 http://dx.doi.org/10.1111/j.0022-3506.2004.00263.x.

27. Hofmann W, Baumeister RF, Förster G, Vohs K: **Everyday temptations: an experience sampling study of desire, conflict, and self-control**. *J Personal Soc Psychol* 2012, **102**:1318-1335 http://dx.doi.org/10.1037/a0026545.

28. Gillebaart M, Schneider IK, De Ridder DT: **Effects of trait self-control on response conflict about healthy and unhealthy food**. *J Personal* 2015, **84**:789-798 http://dx.doi.org/10.1111/jopy.12219.

29. Imhoff R, Schmidt AF, Gerstenberg F: **Exploring the interplay of trait self-control and ego depletion: empirical evidence for ironic effects**. *Eur J Personal* 2014, **28**:413-424 http://dx.doi.org/10.1002/per.1899.

30. Adriaanse MA, Kroese FM, Gillebaart M, De Ridder DT: **Effortless inhibition: habit mediates the relation between self-control and unhealthy snack consumption**. *Front Psychol* 2014, **5** http://dx.doi.org/10.3389/fpsyg.2014.00444 Article 444.

31. Gillebaart M, Adriaanse MA: **Self-control predicts exercise behavior by force of habit, a conceptual replication of Adriaanse et al. (2014)**. *Front Psychol* 2017, **8**.

32. Lin PY, Wood W, Monterosso J: **Healthy eating habits protect against temptations**. *Appetite* 2016, **103**:432-440 http://dx.doi.org/10.1016/j.appet.2015.11.011.

33. Duckworth AL, Gendler TS, Gross JJ: **Situational strategies for self-control**. *Perspect Psychol Sci* 2016, **11**:35-55.

34. Ent MR, Baumeister RF, Tice DM: **Trait self-control and the avoidance of temptation**. *Personal Individ Differ* 2015, **74**:12-15.

35. • Milyavskaya M, Inzlicht M: **What's so great about self-control? Examining the importance of effortful self-control and temptation in predicting real-life depletion and goal attainment**. *Soc Psychol Personal Sci* 2017 http://dx.doi.org/10.1177/1948550616679237.
This paper described a longitudinal study that combined prospective data collection and experience sampling methods to examine whether goal attainment is a function of effortful self-control or avoiding temptations. Results indicated that goal attainment was unrelated to effortful self-control; rather, success was related to decreased exposure to temptations.

36. Duckworth AL, White RE, Matteucci AJ, Shearer A, Gross JJ: **A stitch in time: strategic self-control in high school and college students**. *J Educ Psychol* 2016, **108**:329.

37. Privitera GJ, Zuraikat FM: **Proximity of foods in a competitive food environment influences consumption of a low calorie and a high calorie food**. *Appetite* 2014, **76**:175-179.

38. Stables GJ, Subar AF, Patterson BH, Dodd K, Heimendinger J, Van Duyn MAS, Nebeling L: **Changes in vegetable and fruit consumption and awareness among US adults: results of the 1991 and 1997 5 A Day for Better Health Program surveys**. *J Am Diet Assoc* 2002, **102**:809-817 http://dx.doi.org/10.1016/S0002-8223(02)90181-1.

39. Casagrande SS, Wang Y, Anderson C, Gary TL: **Have Americans increased their fruit and vegetable intake? The trends between 1988 and 2002**. *Am J Prev Med* 2007, **32**:257-263.

40. Mantzari E, Vogt F, Shemilt I, Wei Y, Higgins JP, Marteau TM: **Personal financial incentives for changing habitual health-related behaviors: a systematic review and meta-analysis**. *Prev Med* 2015, **75**:75-85.

41. Wood W, Neal DT: **Healthy through habit: interventions for initiating and maintaining health behavior change**. *Behav Sci Policy* 2016, **2**:71-83.

42. Walker I, Thomas GO, Verplanken B: **Old habits die hard: travel habit formation and decay during an office relocation**. *Environ Behav* 2015, **47**:1089-1106.

43. Lally P, van Jaarsveld CHM, Potts HWW, Wardle J: **How are habits formed: modelling habit formation in the real world**. *Eur J Soc Psychol* 2010, **40**:998-1009 http://dx.doi.org/10.1002/ejsp.674.

44. Adriaanse MA, Vinkers CD, De Ridder DT, Hox JJ, De Wit JB: **Do implementation intentions help to eat a healthy diet? A systematic review and meta-analysis of the empirical evidence**. *Appetite* 2011, **56**:183-193.

45. Turton R, Bruidegom K, Cardi V, Hirsch CR, Treasure J: **Novel methods to help develop healthier eating habits for eating and weight disorders: a systematic review and meta-analysis**. *Neurosci Biobehav Rev* 2016, **61**:132-155 http://dx.doi.org/10.1016/j.neubiorev.2015.12.008.

46. Webb TL, Sheeran P, Luszczynska A: **Planning to break unwanted habits: habit strength moderates implementation intention effects on behaviour change**. *Br J Soc Psychol* 2009, **48**:507-523.

47. Stawarz K, Cox AL, Blandford A: **Beyond self-tracking and reminders: designing smartphone apps that support habit formation**. In *Proceedings of the 33rd Annual ACM Conference on Human Factors in Computing Systems*. ACM; 2015:2653-2662 http://dx.doi.org/10.1145/2702123.2702230.

48. Gillan CM, Otto AR, Phelps EA, Daw ND: **Model-based learning protects against forming habits**. *Cognit Affect Behav Neurosci* 2015, **15**:523-536.

49. Renfree I, Harrison D, Marshall P, Stawarz K, Cox A: **Don't kick the habit: the role of dependency in habit formation apps**. In *Proceedings of the 2016 CHI Conference Extended Abstracts on Human Factors in Computing Systems*. ACM; 2016:2932-2939 http://dx.doi.org/10.1145/2851581.2892495.

50. Chen G, Ding X, Huang K, Ye X, Zhang C: **Changing health behaviors through social and physical context awareness**. *Computing, Networking and Communications (ICNC), International Conference 2015*. IEEE; 2015:663-667 http://dx.doi.org/10.1109/ICCNC.2015.7069424.

51. Verplanken B, Walker I, Davis A, Jurasek M: **Context change and travel mode choice: combining the habit discontinuity and self-activation hypotheses**. *J Environ Psychol* 2008, **28**:121-127 http://dx.doi.org/10.1016/j.jenvp.2007.10.005.

52. • Verplanken B, Roy D: **Empowering interventions to promote sustainable lifestyles: testing the habit discontinuity hypothesis in a field experiment**. *J Environ Psychol* 2016, **45**:127-134.

This paper describes a field experiment which tested the habit discontinuity effect – habit change interventions are more effective during life course changes (e.g. moving house). 800 households were randomly assigned to receive a sustainable behaviors intervention. The intervention was more effective for those who recently relocated.

53. Bamberg S: **Is a residential relocation a good opportunity to change people's travel behavior? Results from a theory-driven intervention study**. *Environ Behav* 2006, **38**:820-840.

54. Thøgersen J: **The importance of timing for breaking commuters' car driving habits**. *Collegium* 2012, **12**:130-140.

55. Thaler RH, Sunstein CR, Balz JP: **Choice architecture**. In *The Behavioral Foundations of Public Policy*. Edited by Shafir E. Princeton, NJ: Princeton University Press; 2012:428-439 http://dx.doi.org/10.2139/ssrn.2536504.

56. Rozin P, Scott S, Dingley M, Urbanek JK, Jiang H, Kaltenbach M: **Nudge to nobesity I: Minor changes in accessibility decrease food intake**. *Judgm Decis Mak* 2011, **6**:323-332.

57. Frey E, Rogers T: **Persistence: how treatment effects persist after interventions stop**. *Policy Insights Behav Brain Sci* 2014, **1**:172-179.

58. Wilson TD: *Redirect: The Surprising New Science of Psychological Change*. UK: Penguin; 2011.

59. Carels RA, Burmeister JM, Koball AM, Oehlhof MW, Hinman N, LeRoy M, Bannon E, Ashrafioun L, Storfer-Isser A, Darby LA, Gumble A: **A randomized trial comparing two approaches to weight loss: differences in weight loss maintenance**. *J Health Psychol* 2014, **19**:296-311 http://dx.doi.org/10.1177/1359105312470156.

60. Kirchner TR, Cantrell J, Anesetti-Rothermel A, Ganz O, Vallone DM, Abrams DB: **Geospatial exposure to point-of-sale tobacco: real-time craving and smoking-cessation outcomes**. *Am J Prev Med* 2013, **45**:379-385.

61. Hackel LM, Doll BB, Amodio DM: **Instrumental learning of traits versus rewards: dissociable neural correlates and effects on choice**. *Nat Neurosci* 2015, **18**:1233-1235 http://dx.doi.org/10.1038/nn.4080.

62. Carden L, Wood W, Neal DT, Pascoe A: **Incentives activate a control mind-set: good for deliberate behaviors, bad for habit performance**. *J Assoc Consum Res* 2017, **2**.

63. Conklin CA, Perkins KA, Robin N, McClernon FJ, Salkeld RP: **Bringing the real world into the laboratory: personal smoking and nonsmoking environments**. *Drug Alcohol Depend* 2010, **111**:58-63.