Nonconscious Behaviour Change Technology: Targeting The Automatic

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CHI'17 Extended Abstracts, May 6–11, 2017, Denver, CO, USA.
ACM ISBN 978-1-4503-4656-6/17/05.
http://dx.doi.org/10.1145/3027063.3048426

Abstract
My research focuses on the use of technology to directly target nonconscious processes to drive behaviour change. It is rooted in habit and dual process theories, and explores the transfer of psychology techniques from labs to smartphones. This paper outlines a set of related experiments and surveys exploring subliminal priming, implementation intentions and cognitive bias modification as potential nonconscious interventions to change behaviour.

Author Keywords
Nonconscious behaviour change; habits; subliminal priming; implementation intentions; cognitive bias modification; smartphones.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous;

Introduction
Nonconscious behaviour change interventions (NCBCIs) are interventions that target automatic cognitive processes, with the goal of behaviour change [18,19]. NCBCIs may aim to create new automatic processes to form new habits, or alter existing processes to break habits. NCBCIs may in themselves be not obvious to the user, e.g. the use of subliminal priming [19], but

"If it weren't for the people, the god-damn people … always getting tangled up in the machinery. If it weren't for them, the world would be an engineer's paradise"

Kurt Vonnegut, Player Piano

they may also require some conscious attention, e.g. where a user plays a 'serious game' to retrain unwanted responses to habit cues [17].

My research focuses on translating theory-driven psychology techniques from labs onto smartphones to explore potential NCBCIs in more realistic settings. The specific techniques were selected for their potential to be ported to smartphones, ability to address the problem, and on theoretical grounds, as outlined below.

The problem

Humans persist in behaviours they know are harmful: the World Health Organisation (WHO) estimate that lifestyle choices account for 61% of cardiovascular deaths [25]. Meanwhile, powerful personal technology is pervasive: smartphone ownership reached 69% in the UK in 2015 [8], with strong growth in wearables [12]. One research question is how best to exploit this technology to support sustainable behaviour change.

My research explores whether the answer may lie in understanding unwanted persistent behaviour as habits. A habit is a learned behaviour that is frequently repeated, is cued by stable contexts and is *automatic* i.e. can be "enacted with little conscious awareness" [15]. The automaticity and nonconscious activation of habits [27] help to explain why behaviour change is difficult and why conscious behaviour change interventions tend to fail [10]. The habit mechanism also creates an opportunity: if interventions can create new habits based on stable contextual cues, then these new behaviours will be persistent [24].

Theoretical underpinnings

My research is based on modern habit theory [11] and dual process theory (DPT) [4]. DPTs suggest that behavioural decisions arise from two distinct sets of processes: a nonconscious set of fast, associative, contextual processes; and a conscious set of slower, rational, rule-based processes. The conscious set has limited resources, so habitual behavioural decisions can arise when the nonconscious set responds automatically to contextual cues. Habits enable an individual can cede control of repetitive behaviour to contextual cues to maintain conscious capacity to deal with unexpected events [7].

One theory-based approach to habit-breaking suggests 'just-in time' (JIT) user alerts about unwanted behaviour as we explored in [3]. However, accurate JIT context- and behaviour-aware detection are unsolved problems, users do not immediately attend to alerts [16], and there is an ongoing risk of *reactance*, users rejecting interventions to preserve behavioural autonomy [2]. Use of pervasive trackers as vigilant monitors [21] to change behaviour has also waned as evidence of abandonment [28] and lack of efficacy in the long term [9] emerge. Trackers also require cognitive resources to view and interpret the data.

My research focus is therefore on a set of low-cognitive load, low reactance interventions on smartphones to form new habits (subliminal goal priming [19] and Implementation Intentions [20]) and time-shifted training to reduce attention to unwanted cues and increase attention to wanted cues using Cognitive Bias Modification (CBM, [17]). A key research question is to establish which techniques are most suitable for further experiments in NCBCIs on smartphones.

Wi-Fi	*Off*	*On*
Length of 1 frame in ms		
Median	16.97	16.97
Max	17.97	18.64
Min	15.99	15.25
Mean	16.98	16.97
SD	0.17	0.19

Table 1 Android frame timings

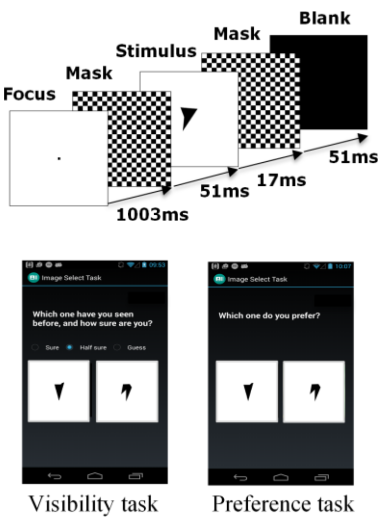


Figure 1 Subliminal study 2's exposure (top) and response (bottom) phases

Experiments

Subliminal Priming

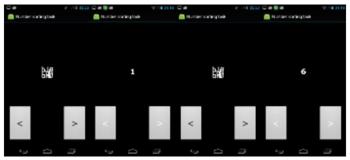
We are running a series of experiments exploring the feasibility and use of subliminal priming on smartphones as follows:

1. A study on the technical feasibility of subliminal priming on Android smartphones;
2. A smartphone study on the immediate impact of subliminal priming on participants' subsequent stimulus preference;
3. A smartphone replication of a desktop-based psychology experiment on semantic processing of subliminal number primes [14]; and
4. A study applying the technique in the wild in a 1-week behaviour change smartphone app [19].

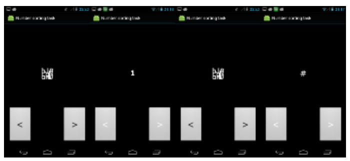
Study 1 measured precise frame times for 1-frame masked stimulus exposures on Samsung Galaxy Nexus phones running Android 4.3. Times with Wi-Fi off and with Wi-Fi on are shown in Table 1. A Kruskal-Wallis test showed no significant differences between frame lengths between our devices with Wi-Fi off ($X^2(3) = 1.42, p=.70$), but a significant difference with Wi-Fi on ($X^2(3) = 18.38, p < .001$). Thus experiments with Wi-Fi off on these phones can show a 1-frame stimulus for ~17ms. These timings are in line with other subliminal research, so we proceeded to Study 2, which explored whether subliminal priming of photos, polygons or text can influence people's subsequent liking of them. Figure 1 (top) shows the procedure for exposing participants to a target prime; Figure 1 (bottom) shows subsequent visibility (which one do you think you saw?) and preference (which one do you prefer) forced-choice questions. Subliminal priming exists where people cannot consciously recall a target item (visibility task, direct effect), but tend to prefer it (preference task, indirect effect). Although our visibility task results did not reach 80% recognition for any stimulus group, we found some visibility issues with face photos and no consistent significant evidence of subliminal priming for n=101 across 3 intervention groups (control, 1 x prime repetition, 3 x prime repetitions). We have redesigned our stimuli and are running further experiments.

In the meantime, we undertook a direct replication of a subliminal priming experiment [14], porting it from desktops to smartphones. The study explores the impact of *novel* number primes on congruent, incongruent, and free-choice categorisation tasks as shown in Figure 2. The original n was 19, but we have data from 150 people, currently being processed. We selected this study because it will demonstrate whether or not subliminal primes on smartphones can trigger activation spread around the prime. Such activation is a pre-requisite for the use of subliminal goal priming in behaviour change applications.

Study 4 is a pre-post-control experiment on the effect of 1 week of incidental subliminal goal priming on implicit and explicit measures of goal strength [19]. We recruit participants who wish to be more active. They receive advice on forming '*active*' goals in line with Goal Setting Theory [13] and are randomly assigned to intervention or control groups. The intervention runs over 1 week. Intervention participants receive a masked subliminal prime of the word 'active' for one frame, approximately 17ms, as shown in Figure 3, each time they unlock their phone. Control participants see only the mask. The experiment app also logs precise frame timings, so we can compare 'in-the-wild' frame



(a)



(b)

Figure 2 Subliminal study 3 (a) congruent and (b) free choice number categorisation examples

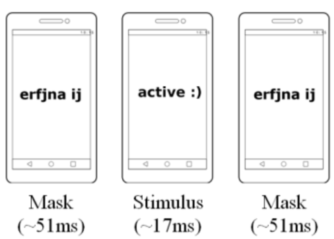


Figure 3: Subliminal study 4's unlock priming procedure

times with Study 1. We are continuing to recruit participants.

Context-aware implementation intentions (IIs)
IIs are *if-then* plans which try to automate behaviour by associating an *if* (a contextual cue) with a *then* (a goal-directed behaviour) [6]. We carried out a 1-week pilot (n=10) to observe IIs formed (Figure 4) and a survey (n=137) to derive design considerations for using context-aware technology to support the formation and execution of IIs [20]. We are particularly interested in the use of proximity beacons to act as additional stable context cues, and asked our survey respondents to identify appropriate locations at home and work situations in which to deploy them. We are shortly running a larger-scale pre-post-control experiment to apply our learnings from both studies. We will deploy 3 different versions of our II app to determine the relative impact of II training, rehearsal and reminders on measures of behavioural automaticity [23] and goal adherence. Participants will be able to use Bluetooth beacons as II-reminder triggers.

Cognitive Bias Modification on smartphones
CBM techniques focus on repetitive training to make particular behavioural cues less salient [17,26]. Technology-mediated CBM has not yet been extensively applied to mobile technology. We built a pilot of an incidental CBM intervention app, where participants had to 'accept' healthy foods (e.g. bananas) and 'reject' unhealthy foods (e.g. crisps) using gestures to unlock their phone [17]. We ran an elicitation study to determine which gestures to select to indicate *accept* or *reject* on this platform. An *accept* unlock procedure is shown in Figure 5. We ran a pilot over 2 weeks or 256 gestures with 22 participants. We found no evidence of changes in implicit food attitudes in our intervention group, but post-experiment surveys indicated agreement that the app supported their healthy food choices, with some frustration with inconsistent gesture recognition when in a hurry. Participants also wanted to personalise the app to their tastes, so we followed up with an exploratory survey (n=58) to find out what pairs of stimuli people wish to *accept* and *reject*. We found that areas of primary concern are food and drink intake, overuse of technology and activity levels [17].

Novelty
NCBCIs are just starting to emerge in HCI [1], where interventions tend to focus on conscious techniques: tracking, goal setting, reminders and providing information are often used [3,22]. Related nonconscious research includes Adams et al.'s study using ubicomp and context cues to alter "mindless" eating behaviour [1]. My research, by contrast, focuses on using existing smartphone technology to deliver NCBCIs. Adams et al.'s also reviewed 176 digital behaviour change papers for those that targeted automatic behaviour, finding only 11, with only 2 mentioning related theory [1]. I similarly found few HCI behaviour change papers use habit as a construct: only 6/136 behaviour change papers in CHI '16 mentioned habit, and only one discussed it in detail.

To my knowledge, our CBM pilot [17] was the first experiment to apply incidental CBM training to smartphones; our subliminal-on-smartphones experiments [19] are similarly novel, for exploring both immediate and longer-term impacts, and we believe we are novel in exploring context-aware tech for IIs [20].

IIs pilot

If ...	Then ...
Movement	Walking 30 minutes a day
Movement	Thin
Location	Sleep tight
Time	Jogging after dinner
Time	Exercise for 10 minutes
Movement	Walking
Time	Drink water
Time	Jogging
Location, Time	Having a dinner
Movement	Walking

Figure 4 IIs formed during the II pilot

CBM pilot

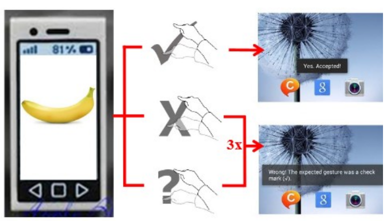


Figure 5 CBM pilot healthy food unlock procedure

Results and contributions to HCI

We have covered much groundwork in implementing NCBCIs on smartphones. We have shown it is possible and acceptable to users to use masked priming techniques on smartphones. We have ported both II and CBM techniques to smartphone apps, and surveyed users about behaviours they wish to alter using them.

Future work

We have yet to demonstrate whether these techniques can contribute to long-term behaviour change, particularly since it may take >66 days to achieve behavioural automaticity [11]. This is the key focus of future research. Once effective NCBCIs have been established, there is still work to do: an approach covering both conscious and nonconscious strategies is more likely to result in sustainable behaviour change than single strand solutions [5].

I am also working on a serious game to retrain implicit gender bias against women. Then I'll trial an app that supports adolescents with mental health issues to retrain negative thoughts. There is much interesting work to be done in the emerging field of nonconscious behaviour change.

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