Under the Radar: Exploring the Feasibility of Subliminal Goal Priming on Smartphones

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ABSTRACT
We outline the novel use of subliminal goal priming on smartphones and explore its theoretical basis. We critically analyse implementation techniques for the approach and report on the technical capabilities of smartphones to deliver it. We outline surveyed user attitudes to subliminal goal priming. We report on a user study of an implementation of the approach and reflect on our qualitative results. We provide recommendations for future research and conclude that subliminal goal priming holds promise in the behaviour change research area, particularly in the emerging field of nonconscious behaviour change.

Author Keywords
Subliminal goal prompting; smartphones; behaviour change technology; nonconscious behaviour change

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

INTRODUCTION
Subliminal priming techniques are common in psychology, but have not been applied to Behaviour Change Interventions Using Technology (BCITs). *Priming* is the showing of a stimulus with the aim of activating related mental concepts; s*ubliminal priming* is the practice of priming without attracting conscious attention of the recipient; and s*ubliminal goal priming* is the display of stimuli intended to automatically activate the mental representation of a goal and thus increase the likelihood of its pursuit [40].

Why might we need to employ subliminal goal priming in BCITs? Dual process theories (DPT, see Evans [19] for a review) suggest that our decision-making structures are comprised of two sets of processes: a fast, heuristic, associative, automatic nonconscious system and a slow, rational conscious system with limited resources. Much of everyday life is determined by mental processes triggered in the nonconscious system by contextual features [5]. Approximately 45% of human behaviour is habitual, i.e. automatic behaviour deriving from the nonconscious system cued by context [33]. Priming techniques directly target the automatic system, rather than attempting a more attenuated method of behaviour change via the (limited) conscious system.

Whilst the automaticity of habitual behaviour makes it resistant to conscious strategies to change, we can also potentially exploit this mechanism. We may induce people to perform new behaviours by instilling goals in the nonconscious system, then priming those goals [36,46].

RELATED WORK
HCI research has explored the use of subliminal techniques in driving, teaching and selection [4,10,15,37]. However, the emphasis is on just-in-time selection, i.e. trying to support users in immediate tasks. Likewise in persuasive technology research and design, the majority of interventions focus on just-in-time conscious reminders, goals and provision of information [2,34,43], despite evidence that these techniques do not promote long-term user interaction [41,47].

The observed decline over time in user interest in conscious activity reminders may be explained by *reactance*, where users react adversely to a perceived loss of freedom of behaviour [8]. Reactance has been explored in a BCIT featuring artificial social agents [38], but little research has been dedicated to exploring how people react when their smartphones or other wearable devices tell them what to do.

Exceptions to the conscious BCIT paradigm tend to use glancaeable or subtle interventions, such as the UbiFit system with a glanceable display of goal progress [11] and a "subtle but perceptible" aural feedback system to try to influence user speaking pitch [2]. However, the impact of these systems may fall either on the conscious or nonconscious systems (or both): it is not easy to disambiguate the effects.

Instead, we explore the use of subliminal *goal* priming – the use of subliminal techniques to drive goal pursuit [1,7,39]. By definition, such techniques can only affect the nonconscious system. Several apps purporting to employ the technique exist, although their research base is unclear, the

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length of time suggested is often above the liminal threshold (300ms, [30]) and use phrases as stimuli of a length that are unlikely to be read in short display times (<50ms) [25].

There is evidence that using subliminal priming techniques can help to avoid user irritation [22], be less likely than conscious prompts to promote behaviour in contrast with the goal [21], and ensure authenticity in response [40].

DESIGN CONSIDERATIONS

Prime mode

Riener et al. identified four possible channels of subliminal communication: visual; auditory; olfactory and tactile [37]. We selected visual as the most suitable channel for priming on smartphones: auditory signals may not be attended to and phone sounds are often disabled; there are few tactile opportunities on a static touchscreen; and research into olfactory HCI on smartphones is in its infancy [27].

Within the visual priming mode, there are a number of additional design factors. Firstly, how to deliver the prime? Social psychology experiments often use concealed but supraliminal methods of priming, e.g. word search [6], which are unsuitable for small screens. Subliminal priming – showing a goal prime for a short space of time – is much more suitable for small screen usage. Secondly, in what format should the prime be delivered – as an image or a word? Although there is evidence that images activate meaning faster than words [9], the selection of an image with intrinsic and general meaning is more difficult than the selection of a word. To maximise the likelihood of any given prime activating related concepts, single words are preferred to phrases because they are easier to parse.

Subliminal word primes should avoid ironic effects – for example "no smoking" is *not* suitable as a prime [18]. Similarly, the evidence for using goal priming as a habit-breaking strategy is mixed [46]. Therefore, a target goal should be selected that is a positive behavioural change that may eclipse the existing unwanted bad behaviour.

Affect

Research shows that subliminal conditioning (linking subliminal stimuli to positive affect) can influence choice behaviour even where that behaviour doesn't address an immediate need [45]. We therefore suggest adding simple affective cues to stimuli in the shape of smilies :) or ☺.

Further, there is evidence that the mere exposure effect also extends to subliminal cues: such stimuli shown repeatedly are rated more positively than single-shot stimuli [31]. It is therefore possible that merely repeatedly showing subliminal goal stimuli on a smartphone could increase goal liking, which in turn may therefore increase the likelihood of goal achievement [12].

Timing & masking

There is some debate about appropriate timings for subliminal primes. There is evidence that a word shown for 33ms (i.e. 2 frames at 60Hz/frames per second) is visible when shown in isolation, but invisible when a pre- and post-mask of geometric shapes is applied. Other systems have used durations ranging from 1/180th of a second [15], 4ms [32], 16.67ms (i.e. 1 frame at 60fps) [16,44], 30ms [45] to 33ms (2 frames at 60fps) [48]. We selected a target show rate of 10ms.

The second timing issue is when we might expect users to be looking at their phones: we selected unlock time as a time at which we can be reasonably confident that users are looking at their phones, and suggest restricting experiments to users with unlock patterns or pins. Based on data showing an average of 55 uses per day [23], together with research suggesting subliminal goal priming effects can hold over 24 hrs [42], we have ample opportunities to intervene.

User attitudes

A key question is whether users would accept subliminal priming techniques. In a survey of users of activity trackers, we asked "Would you consider enabling subliminal prompts on your device?" and for comments. 26 people responded to either or both questions and the results are shown in Table 1.

Response	Definitely	Neutral	Definitely not	No rating
Count	1	13	7	5

Table 1 User responses to subliminal prompts question

The participant that responded "Definitely" said, "*Curious how and if this could work?",* while reasons for responding "Definitely not" included scepticism over effects ("*Don't think it's useful*"), a rejection of the idea of subliminal prompting ("*be obvious or not at all*"; and possible fear about the technique ("*subliminal prompts sounds like it could scar[e] people*"). Neutral respondents also expressed possible fear ("*it does make me aware of the fact that anyone could [p]ut any sort of subliminal message in my devices and I wouldn't like that*"), and wanted subliminal prompts that would comply with their conscious goals ("*the messages should comply with my other … goals and not conflict with them*"). We therefore suggest that any BCIT employing subliminal techniques should ensure they address user fears and misunderstandings at the outset.

FEASIBILITY STUDY

We built an Android app that displayed the phrase "active :)", saved as an image with a white background, 50ms after the User Present action was received (i.e. shortly after unlock). The image was set to display for 10ms. To test the display time, we used a phototransistor (Osram Opto SFH 309-3/4) with a fast typical rise and fall time (7µs) attached to an Arudino schematic to measure the length of time the prompt appeared on a Motorola XT1032 running Android 4.4.4 with Wi-Fi enabled over 70 trials. The average time of goal phrase image display in milliseconds can be seen in Table 2. On average, the goal prompt appeared for less than 10ms, with a maximum display time of 17ms. This

demonstrates that showing primes for a very short space of time is feasible on relatively low spec Android devices.

Mean	7.14
SD	4.38
Max	17
Min	2.5

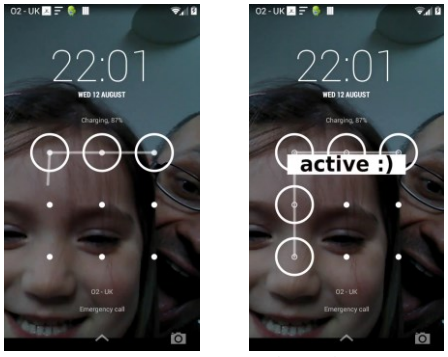
Table 2 Goal prompt display times (ms)

USER STUDY

We carried out a small user study to further explore the technique. 10 participants (5 females, 4 males, 1 unknown) were recruited from University of Anonymised students and staff. All participants gave informed consent and were given £5 for participation.

All participants were asked to consider and accept a goal of being more active by always taking the stairs when they were moving less than 5 floors. Participants then completed a pre-intervention survey assessing Goal Commitment, items 4-8 on the Hollenbeck, Williams, and Klein (HWK) scale [24] as validated by [14] on a 7-point Likert scale. Mask condition participants (n=5) then installed an Android app that showed the word "active :)" for 10ms, 50ms after they unlocked their phone as shown in Figure 1.

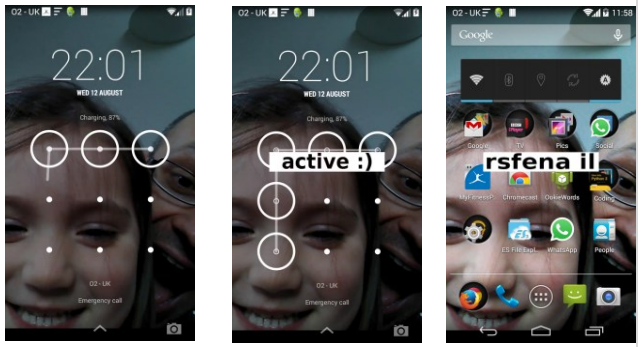
The app for mask condition participants (n=5) was identical except it additionally showed a nonsense word as a mask for 50ms immediately following the goal prime, as shown in Figure 2. We selected the word "active" because it is commonly understood to form part of a general action goal [3].



Blank for 50 ms | Shown for 10 ms

Figure 1 No mask condition screenshots

After one week, participants uninstalled the app and again completed the Goal Commitment survey. They also rated items on reactance, system likeability and perception of usefulness on a 7-point Likert scale. The questions are given in the supplementary material.



Blank for 50 ms | Shown for 10 ms | Shown for 50 ms

Figure 2 Mask condition screenshots

Results

Measure	Mask condition				No mask condition			
	Pre		*Post*		*Pre*		*Post*	
	M	*S.D*	*M*	*S.D*	*M*	*S.D.*	*M*	*S.D*
Goal commitment	3.2	1.09	3.15	0.37	3.5	0.95	3.3	0.83

Table 3 Goal commitment scores

Table 3 shows the responses to goal commitment questions for our two different groups and two different intervention sessions (pre- and post-). A data error meant that only post-test scores for item 8 on the HWK scale was recorded, so this item was excluded. The scores given are all equal to or lower than average, indicating that the participants did not feel very committed their goal at the outset.

Reactance

Following Dillard & Shen [17], we computed a reactance measure as the mean of the reverse score responses to the items annoyance, irritation, aggravation and anger. The results are shown in Table 4, with frequency of responses shown in Figure 3. On average, participants across conditions reported little reactance to the intervention, and no participants scored any negative emotions at 6 or 7. No participants in the mask condition scored any negative emotions at 5 or above, while one no mask participant scored them all 5, indicating some reactance to the intervention.

	Mask		**No mask**	
	Mean	*S.D.*	*Mean*	*S.D.*
Reactance	2.25	0.75	2.15	1.76
Likeability	3.73	1.19	4.93	1.67
Perception	3.9	0.89	4.8	1.03

Table 4 Aggregate self-report scores

Likeability

Reverse scores of Helpful/Not Helpful, Easy to Use/Not easy to use and Enjoyable/Not Enjoyable ratings were averaged to give the likeability score in Table 4. The results suggest users did not dislike the system, supporting our reactance results.

User perception

We reversed scored our user perception scores and averaged them to derive the measure in Table 4. The frequency of Likert responses is shown in Figure 4, indicating that participants were somewhat neutral about the impact of the technique, in line with our user survey, although participants in the no mask condition were more positive, perhaps because they were not shown a nonsense word and were more likely to consciously perceive the "active" prompt.

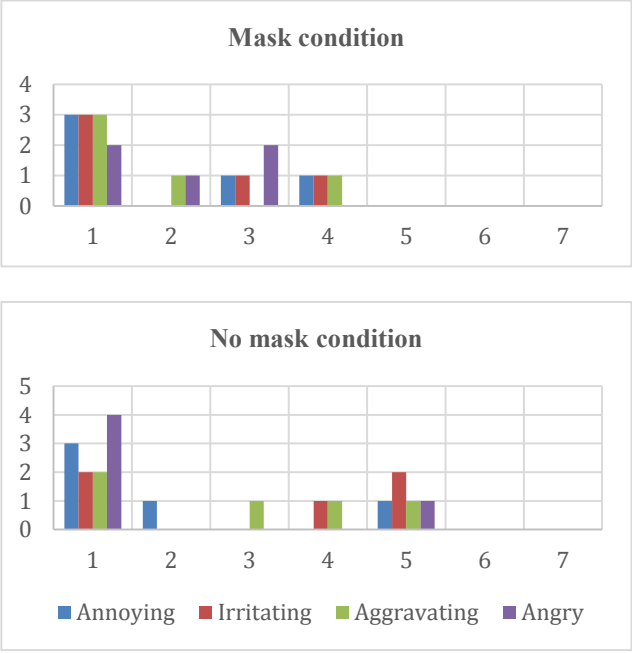


Figure 3 Frequency of responses to reactance questions

Feedback

2 participants (40%) in the no-mask condition reported seeing the goal word, while 2 participants (40%) in the mask condition reported that they could not recognise the goal word.

DISCUSSION

We have demonstrated that subliminal priming is feasible on smartphones. All participants reported relatively low goal commitment scores, which may be related to our use of a pre-determined external goal with only brief goal training [39]. We suggest a more intensive goal-training session is required to guide participants through selecting their own goal in line with Goal Setting Theory (GST, [28]), and ensure that participants associate their self-selected goal with the goal prime (i.e. the word 'active').

2 of the 5 subjects in the no mask condition reported reading the goal word. We therefore suggest using post-prime masking to ensure that participants do not consciously notice primes. This recommendation is supported by evidence that the effect of goal priming is reduced or even removed when the same primes are visible [20].

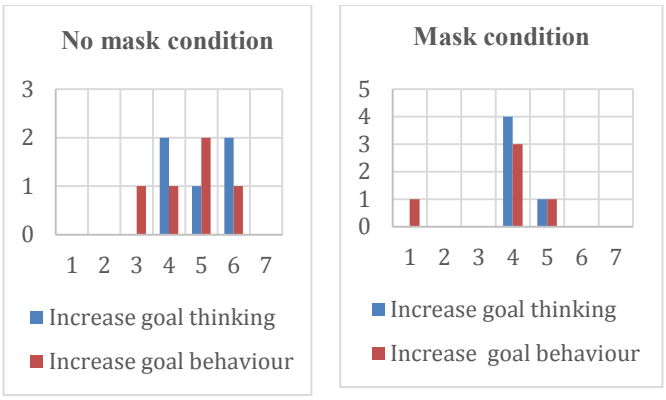


Figure 4 Frequency of responses to user perception questions

FUTURE WORK

There are many ways in which this paradigm could be incorporated into existing displays on smartphones, smartwatches and other displays. For example, a smartwatch time display could include a 10ms goal image, using the time numerals to mask the prime. Further quantitative analysis should be completed to determine the length of display times of different primes on devices under different conditions (e.g. Wi-Fi on/off, Bluetooth on/off).

Further quantitative analysis is also required to explore the impact of the technique on measures of goal commitment, reactance and behaviour over a longer intervention time. A longitudinal study is particularly important in BCIT research where the targeted behaviour is habitual, since habits may take from 18-254 days to form [26]. Assessing goal commitment for nonconscious goals is difficult [42], so future experiments should incorporate non self-report measures of goal activation such as emotional Stroop [35] and/or Dot Probe Tests [29].

Future experiments should use a longer pre-intervention session to ensure the relevant goal is accepted by the user so it is present for priming i.e. to try to achieve high scores for goal commitment at the outset. The guidelines for such goals should follow GST [28]. A further interesting area of research is the interaction between subliminally primed goals and conscious goals [42].

We have demonstrated that the novel technique of subliminal goal priming is possible on smartphones. We have found qualitative support for the idea that the technique does not alienate users, and suggest further research to determine the efficacy parameters of this exciting area of nonconscious behaviour change.

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