Practical Recommendations for Examining Subliminal Techniques in Ubiquitous Computing

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ABSTRACT

In an attempt to provide users with more information while maintaining a calm ubiquitous environment, designers have investigated the possibility of presenting information "subliminally". We explore the historical issues associated with examining perception without awareness; one of those issues is the difficulty associated with ensuring stimuli have been presented below the participant's subjective threshold of awareness. It may be possible to circumvent this issue by taking a results-oriented approach. We make five recommendations for designers interested in using subliminal techniques. In these recommendations we provide methods to gauge participant awareness and encourage designers to examine the importance of perception without awareness within their specific ubiquitous information sources. Before we can continue the advance of insightful uses of subliminal techniques, we need to explore whether or not information presented below the subjective threshold of awareness will have a practical effect on user performance.

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INTRODUCTION

Our interaction with computing technologies has rapidly changed over the last decade through the exponential growth of technology. This growth has resulted in smaller and less expensive computing devices filling our surroundings and creating a Ubiquitous Computing (Ubicomp) environment. When interactions are too prominent, though, they can become overwhelming [e.g., 29]. In order to retain a calm environment, technology must fade into the background of our daily tasks. One way to accomplish this is to embed technology, unobtrusively, into the environment and create "natural" user interactions with the intent of keeping interactions at the periphery of attention [16, 26, 25, 29]. A second way to facilitate a calm environment is to limit users' awareness of the information source. Here instead of disguising information or relegating it to the periphery, the goal would be to prevent users from even realizing the information had been presented. Subliminal presentation, or subliminal persuasion, involves just that. Researchers hope to influence behavior through the subconscious presentation of information [e.g., 4, 8, 22].

We will provide a working definition of what it means for something to be subliminal, detail the difficulties associated with measuring subliminal effects and ensuring subliminal presentation, and provide practical considerations for designers who may be interested in using subliminal presentation of information. We believe that whether the designer wants to present information at the periphery of attention, create "natural" interactions, or present information subliminally, there is a common goal, to create a user experience that requires fewer cognitive resources to be spent on secondary tasks. This common goal underlies our practical recommendations for using subliminal stimuli.

DEFINING THE SUBLIMINAL EXPERIENCE AS PERCEPTION WITHOUT AWARENESS

Much of the original debate surrounding subliminal perception concerned the definition of *subliminal* and the related issue of determining how to measure the influence of subliminal stimuli [3, 7, 20]. In response to some of the controversy, many psychologists have abandoned the term *subliminal* in exchange for terms that capture stimulus effects and participant perception – the subjective threshold and the objective threshold of awareness [6]. Stimuli exceeding this *subjective* threshold have a measurable effect on behavior (thoughts, emotions, actions) and are perceived by participants (i.e., participants claim to have awareness of the stimuli). Stimuli exceeding the *objective* threshold also have a measurable effect on behavior but participants claim not to have detected the stimulus. A stimulus that does not appear to affect performance in any way is assumed to have been presented below the objective threshold. Thus, stimuli presented above the objective threshold, but below the subjective threshold are the most analogous to the concept of subliminal presentation [see 23 for a similar operational definition of "subliminal"]. Individuals in this state are often referred to as having perception without awareness.

There is evidence supporting the existence of perception without awareness. In one very simple task described by Merikle and Reingold (1992), participants are presented with a briefly displayed (e.g., 50 msec) stimulus (a word or a blank screen) that is forward and backward masked;

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masking serves to move this easy task below the subjective threshold for most participants. After stimulus presentation, participants are shown two words and asked if either one of them had just been presented. This question is meant to test subjective awareness, or detection, of the stimulus. Then participants are given the same two words and asked which one was presented. This recognition question is meant to test whether or not the stimulus exceeds the objective threshold. The results of this type of study consistently show that even when participants do not report seeing the stimulus, they occasionally have processed the stimulus as they perform above chance on the recognition task. Similar results have been found using a number of stimulus types and contexts [e.g., 8, 18, 27], providing clear evidence that participants can be affected by stimuli for which they have no awareness.

ESTABLISHING PURE SUBLIMINAL PROCESSING IS A CHALLENGE

Despite the now convincing evidence for perception without awareness, many difficulties remain in the interpretation of these data. One of those difficulties lies in determining the validity of measures of awareness. The most common measure of awareness is participant self report. For instance, a researcher might simply ask participants whether or not they had detected the stimulus; if they say "no", any effect that is obtained might be attributed to "subliminal" effects. Unfortunately, self-reported awareness is subject to bias and may not be a pure measure of conscious perception [e.g., 13, 24]. In a visual detection task, for example, participants may set different criteria when determining whether or not they detected a stimulus with one participant setting a strict criterion – I will only say I saw something if I can describe what I have seen – and another participant setting a lax criterion – I will say I saw something if I have a hunch something was there. Given the same amount of perceptual information, and presumably the same underlying processes, these participants would provide divergent evidence whereby one appears to have been aware of the stimulus while the other has not. Cheesman and Merikle (1984) suggest that this type of bias results from decreased participant confidence during difficult identification tasks.

In addition to participant biases, one must consider what information participants use during detection and recognition tasks. It is often assumed that when a stimulus is not detected, participants base their recognition judgments on information that is unavailable to awareness; this simply may not be true. It is possible that the recognition task is based on partial awareness of the stimulus [see 6 for additional discussion]. For example, consider a participant completing a word identification task like those described by Merikle and Reingold (1992). In a relatively straightforward case, the participant may have been aware of the identity of one letter in a briefly flashed stimulus, but was not confident enough to say they detected a word. Awareness of that one letter could be used during the recognition task, thereby boosting their performance above chance. It may be the case that correct decisions can be made when even less evidence (e.g., line segment or feature) is available to awareness [for a detailed discussion of participant confidence see 17]. Therefore, participant bias and the lack of evidence for pure processes (e.g., a task only sensitive to aware or only sensitive to unaware processing) can severely limit our ability to make strong claims regarding the "subconscious" processing of stimuli. Even in laboratory settings, it is extremely difficult, if not impossible, to ensure that a stimulus is presented below the threshold of awareness [19, 24]; this problem is only compounded in a more naturalistic setting.

RECOMMENDATION 1: SUPPORT CLAIMS OF AWARENESS WITH DIVERGENT RESULTS AND MULTIPLE TASKS

Do the inherent difficulties associated with "subliminal" stimulation preclude its use or undermine its value? Not necessarily. Practical use of this cognitive ability may be possible if we reframe the issue of awareness in terms of behavioral outcomes. Instead of focusing on whether or not a stimulus is detectable, consider whether or not a set of tasks or conditions produce dissociable effects [8, 14, 19]. Merikle and Reingold (1992) recognized the difficulty in "proving" the existence of pure processes and measures of perception without awareness and focused instead on differential outcomes related to reported aware and unaware states. With this mindset, if a researcher establishes two conditions, one where they believe participants will be aware of the stimulus and another where they believe participants will be unaware of the stimulus, *and* the results show that those manipulations have differential effects, then those results have provided additional evidence that distinct processes may underlie the two inferred states.

Alternatively, Merikle and Reingold (1992) suggested using direct and indirect measures to infer the underlying processes at work. For instance, in addition to asking a participant whether or not they detected a word (direct measure of perception) one might ask them about their preference for that word (indirect measure of perception – participants tend to prefer stimuli they have seen before more than novel stimuli). Although indirect measures do not offer a direct examination of participants' awareness of a stimulus, they can be valuable. For example, Riener (2012) presented vibrations below the threshold of awareness in an attempt to encourage individuals to adopt energy saving driving strategies. In the study, participants were exposed to "subliminal" vibrations in their seat and safety belt; when participants drove in a way that did not conserve energy they received disharmonic vibrations, when they drove in a way that conserved energy they received harmonic vibrations. At the end of the study, participants were asked whether or not they noticed the vibrations; this is a direct measure of stimulus awareness. All but two participants (15%) reported being aware of

vibrations at some point during the experiment. Participants said the vibrations were not distracting or annoying and they did not intentionally change their driving behavior in response to the vibrations. During the experiment, researchers monitored participant driving behavior; this is an indirect measure of the influence of the stimulus. In this experiment the indirect measure of driving behavior is just as important – if not more so – than participants' self-reported awareness of vibrotactile notifications.

When faced with the problems associated with "proving" that stimuli have been presented below the threshold of awareness, it is useful to have multiple measures (e.g., direct and indirect) with differential sensitivity and to carefully examine the results. If divergent results are found across two measures – for example, the indirect measure reflects influence from the stimulus but the direct measure does not – it provides convergent evidence that two distinct processes may have been measured.

REFRAMING THE QUESTION OF AWARENESS

It is difficult to effectively use subliminal presentation. Determining participant awareness of stimuli and determining the psychological processes underlying performance is challenging and, oftentimes, the results are inconclusive when carefully examined [14, 20]. When we become wrapped up in these details we can lose sight of the primary reason for using "subliminal" presentation, which is to present information to users in a way that is less disruptive and less resource consuming. In most psychological experiments this is not the goal. The goal is to examine the underlying mental processes supporting a task. For the experimentalist, it is therefore extremely important to have a clear delineation between aware and unaware processing. The same may not be true for the practitioner. To illustrate, imagine a virtual button that provides subtle contrast cues that encourage users to act on it over other buttons. The visual difference between the higher contrast button and other buttons is so slight that participants report being aware of the difference 40% of the time. This visual nudge would guide users through an interface. Imagine that this contrast manipulation leads to faster and more accurate task completion. In this case, does it matter that participants sometimes were aware of the cue? Probably not, because we have accomplished our goal of improving interface navigation.

RECOMMENDATION 2: MEASURE AWARENESS IMMEDIATELY

With this new focus on outcomes, we would like to provide some practical suggestions for determining awareness of stimulus presentation as well as determining effectiveness of stimulus presentation. Our first recommendation is the use of multiple tasks, or measures, of stimulus awareness and effectiveness (e.g., direct and indirect measures) as previously discussed (refer to "Support Claims of Awareness with Divergent Results and Multiple Tasks"). Our second recommendation is to get the most from your measures. The assessment of self-reported user awareness of a stimulus provides an excellent case in point. Numerous pitfalls associated with self-report have already been discussed, but an additional pitfall concerns memory. Many stimuli that are presented near the subjective threshold of awareness have "weak" signals and can be forgotten rapidly if other competing stimuli are present [21]. Thus participants may be briefly aware of a stimulus, but if they do not focus attention on that percept, the memory of it may be lost. If participants are only asked at the end of the experiment about their experience, they may truthfully say that they did not notice the stimulus, when in fact they were aware of it at one point and simply forgot [e.g., 9]. To get the most out of subjective reports of awareness, it is important to probe the participant very soon (immediately, if possible) after presentation of the stimulus. The longer the delay, the larger role memory will play in self-reported awareness.

If we were to implement this recommendation in Riener's (2012) driving and vibrotactile feedback study, this would mean asking participants whether or not they notice a vibration while they are completing the driving task. Granted, questioning participants while they drive could affect their performance, but if this is done in each of the diving conditions (e.g., drivers asked about awareness three times during each of the driving segments), the effects would be equally detrimental preserving the validity of the comparisons between conditions. Researchers might also be concerned that asking participants about the presence of a "subliminal" stimulus would change their behavior as they wonder why they are continually questioned about the stimulus. One way to accommodate possible behavior changes is to counterbalance the order of driving conditions so that the cumulative effect of continued questioning is experienced in each of the driving manipulations across participants. Another way to counteract participant strategy changes is to disguise the purpose of the questioning by asking irrelevant questions as well. For instance, if you are interested in participant detection of vibrations, ask about other sensations as well - "did you hear any high pitched noises?", "did you see any lights flash?". Not only would these questions diffuse participants' focus on the vibrations [see 23 for a similar concern], they could serve as a measure of participant bias. Specifically, as sounds and flashes were not presented, participants' spurious responses give a general indication of how likely they are to report something that was not present and could not have been detected (i.e., guessing behavior).

RECOMMENDATION 3: USE SEVERAL STIMULUS INTENSITIES

Another way to get the most from your measures is to use several levels of stimulus intensity. We have already discussed participant biases in regards to decision making (e.g., how much evidence does it take for an individual to

say they have detected a stimulus), but it is also the case that participants have different perceptual abilities. Thus, it is seldom the case that one stimulus intensity will fall between the subjective and objective thresholds for all participants. In addition, as participants continue with a task, their subjective threshold may change. Typically the threshold moves lower such that originally undetected stimuli are more likely to be detected toward the end of the experiment [e.g., 6]. One way to combat this issue is to set the stimulus intensity for each participant and update it throughout the experiment. An alternative would be to include several levels of stimulus intensity (some near the subjective and objective thresholds of awareness) in the experimental design. The most obvious benefit to using multiple levels of stimulus intensity is that each participant is guaranteed to be presented with stimuli below the threshold of awareness without varying intensities across individuals or during an experiment. When this practice is paired with frequent probing of participant awareness, researchers can have a better understanding of participant awareness during the task and its relation to performance. This approach is particularly useful when conducting pilot studies.

In addition, it has been shown that different effects can be obtained based on stimulus intensity. This is true even when awareness is not a factor. For example, a series of studies examined the contributions of orthography (letters) and phonology (speech sounds) to word recognition using masked and briefly displayed nonword primes [e.g., 10, 11]. Specifically, Grainger and Ferrand (1994) used nonword primes that shared several letters with the target word and had the same pronunciation (e.g., French stimuli *mert – mere)* or shared fewer letters but again had the same pronunciation (e.g., *mair – mere*) with the target word. Prime exposure duration was also varied: 14, 29, 43, and 57 msec. It is generally accepted that masked word primes with exposure durations of 60 msec or less fall below the subjective threshold of awareness for most participants, therefore, all four levels of stimulus intensity would be considered "subliminal". Across several experiments it was demonstrated that participants were faster to recognize a target when it shared orthography with the prime at 29- and 43-msec exposure durations; by contrast, facilitation for items with similar phonology occurred at 43- and 57-msec exposure durations. Based on results like this, the authors proposed that phonological processes occur later or take longer than orthographic processes. If they had only examined very short prime exposure durations they may have concluded that phonological processes require participant awareness of the prime, when that clearly is not the case. Thus, unexpected, but potentially important, characteristics of the task or underlying processes can be revealed when multiple stimulus intensities are used. Even if a researcher is not interested in those nuances, there is a practical reason to use multiple stimulus intensities; it increases the odds of finding an effect.

RECOMMENDATION 4: DETERMINE THE IMPORTANCE OF AWARENESS BY EXAMINING OUTCOMES

Our fourth recommendation is to determine whether or not participant awareness of the stimulus really matters. One way to determine this is by examining behavioral outcomes [19 make a similar recommendation]. Some processes, and participant's subsequent behaviors, are greatly affected by awareness of the stimulus [e.g., 3]. For example, Jacoby, Toth, Lindsay, and Debner (1992) describe an unpublished study by Chalfonte that was aimed at investigating participants' ability to solve anagrams when given the solution beforehand. The solution was either briefly presented and masked, preventing participants from recognize it, or was unmasked allowing participants to recognize the word. Participants were asked to try to identify the briefly presented word, solve the anagram, and then report how difficult the anagram would be for others to solve. As long as the time between solution and anagram presentation was short (500 msec), participant anagram solving was facilitated regardless of their initial awareness of the solution. Interestingly, participants who had not "seen" the solution predicted that the task would be easier for others while participants who reported seeing the solution did not change their difficulty rating. In other words, participants in the unaware condition misattributed the ease of solving the anagram to the anagram difficulty (e.g., it was an easy one) instead of to the fact that they had been given the solution. By contrast, when participants knew they had been given the solution, they did not make the same misattribution. In this case, it is clear that stimulus awareness affected behavioral outcomes.

A logic-based, problem-solving study also provides an example in which awareness of an information source would likely affect behavioral outcomes [5]. Participants were given problem-solving exercises (partially-completed Magic Squares) and were primed with a neutral prime (only pattern masks), the solution to the problem (arrow pointing to the correct answer location), or a miscue (arrow pointing to an incorrect location). The primes were displayed for 33 msec and pre- and post-masked limiting awareness of the prime. The results indicated that valid cues facilitate performance whereas miscues had no effect. Presumably, if participants were aware of the prime their accuracy might be expected to change because they would then have the opportunity to notice the consistent reliability/unreliability of the cue.

In other cases, awareness of the stimulus has very little effect on participant responses and attributions [e.g., 12]. In a word recognition study, participants are asked to decide whether or not a given letter string – the target – was a word (lexical decision task). By presenting a prime with a similar spelling before the target, one can hinder or facilitate target processing. Instead of using a similar prime, Forster (1998) used an identity prime, the prime and target were the same word (e.g., *fork* - FORK), and either used a

briefly displayed, masked prime or a clearly visible prime. Regardless of prime awareness, participants made faster lexical decisions to targets after presentation of an identity prime. These results present a clear case of how participant awareness of an information source does not always matter.

From a practical standpoint the consideration is this, does awareness of the stimulus have a meaningful effect on behavioral outcomes? If not, perhaps ensuring "subliminal" presentation becomes a secondary concern. Many researchers have taken a similar approach by not focusing on participant awareness but instead examining how encountering a stimulus can, unbeknownst to the participant, affect their future behaviors [e.g., 1, 2]. There are cases when even warning participants about stimulus influences fails to attenuate the influence of that stimulus [e.g., 13]!

Given that some behavioral outcomes are greatly affected by stimulus awareness, whereas others are not, it is important to know which is true for the task at hand. If awareness of a stimulus has little effect on participant performance, perhaps it is less important to ensure stimuli are always presented below the threshold of awareness.

RECOMMENDATION 5: EXAMINE RESOURCE REQUIREMENTS

We have just advocated that when awareness of a stimulus appears to have no effect, one could be justified in disregarding participant awareness of the stimulus. But, this is not our full intention. One must also consider the resources associated with stimulus awareness and how resource use could interact with concurrent tasks. One of the goals of subliminal presentation is to present information without taxing cognitive resources. Resource consumption continues to be a concern even if a behavioral outcome appears to be unaffected by stimulus awareness. Even when no effect of awareness is detected in one situation, adding another task or slightly changing the task could alter resource requirements leading to an unexpected, adverse effect. According to Wickens (2008), some multiple task workloads use independent resources (light interference), while others are dependent on similar resources (heavy interference). For example, it has been suggested that visual and auditory information can be maintained independently because they rely on different resources. In this context, awareness of a stimulus would matter most when the resources required to process that stimulus are the same as those required for the primary task. Utilization of the same resource can lead to task errors. Therefore, before deciding that participant awareness of a stimulus is acceptable, one should consider the resources associated with that awareness.

Riener's (2012) driving study provides a valuable illustration of resource requirements. In the original study, participants were presented with subtle vibrotactile feedback related to their driving behavior. If the driving task relies primarily on the interpretation of visual information, then perception of tactile sensations is unlikely to use the same resources, therefore one might not expect a decrease in driving performance even when participants are aware of the vibrations. Consider, by comparison, what would happen if a visual stimulus was used. Imagine a word such as *conserve* was presented on a heads up display to users. It is possible that recognition of that word would tax the same pool of resources being used for the driving task leading to a performance detriment. In this hypothetical situation, it is more important for visual feedback to be presented below the threshold of awareness than it would be for tactile feedback to be presented below the threshold of awareness.

CONCLUSIONS

As we become more immersed within a highly computationally-driven environment, new human-computer complexities are going to arise. Maintaining calm and natural surroundings, given that we are immersed within computational information sources, will continue to be of the utmost importance [16, 25]. One strategy would be to limit the number of devices that demand our limited conscious resources as has been an ongoing goal in Ubicomp. Another strategy is to increase understanding of stimulus processing within our natural environment. Researchers and designers have incorporated this understanding into user interface design, but some aspects of this have been a challenge. The use of "subliminal" presentation of information has presented one of these challenges. We believe careful examination of subliminal processing and reconsidering our goals when using subliminal techniques, can lead to productive and insightful outcomes. We have attempted to delineate some of the issues encountered when using subliminal techniques (e.g., definition of *subliminal*, measuring and interpreting subliminal effects) and provide practical recommendations and considerations for using subliminal presentation techniques.

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