CloakingNote: A Novel Desktop Interface for Subtle Writing Using Decoy Texts

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ABSTRACT

We present *CloakingNote*, a novel desktop interface for subtle writing. The main idea of *CloakingNote* is to misdirect observers' attention away from a real text by using a prominent decoy text. To assess the subtlety of *CloakingNote*, we conducted a subtlety test while varying the contrast ratio between the real text and its background. Our results demonstrated that the real text as well as the interface itself were subtle even when participants were aware that a writer might be engaged in suspicious activities. We also evaluated the feasibility of *CloakingNote* through a performance test and categorized the users' layout strategies.

Author Keywords

Subtle Interface; Shoulder-Surfing Problem

ACM Classification Keywords

H5.2. Information interfaces and presentation (e.g. HCI): User Interfaces-Input devices and strategies, evaluation

INTRODUCTION

Along with the proliferation of desktops and mobile devices, people can and want to access their digital devices anywhere and anytime. However, in some social situations people have to refrain from doing so. For example, according to a survey [3], people want to send a personal message/email or update social network status at work. However, they are reluctant to do so because they do not want their employers and colleagues to notice that they do personal things at work. Privacy issues (i.e., shoulder-surfing problem [10]) also influence people's behavior in such situations.

We observe that people resort to simple strategies to hide their private activities in such social situations. For example, desktop users may continue their activities using a small device (e.g., smartphone) [3], minimize screen brightness, turn the screen away from others' sight, or quickly switch to different applications upon detecting another approaching. Although such strategies can hide private contents from people nearby, they may expose users' intention to hide.

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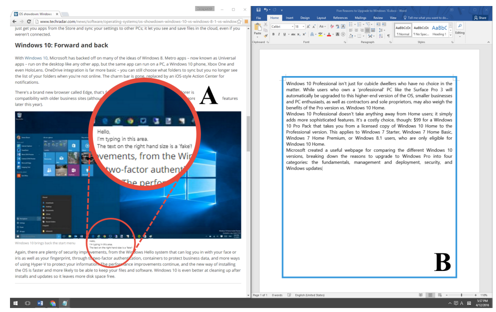


Figure 1. *CloakingNote* convinces observers that a user is writing a decoy text (B) while concealing a real text (A).

Therefore, users have to take a risk that other people can notice that they have tried to hide something.

To help users in such situations, previous studies have proposed methods for subtle interaction but at the cost of performance degradation. For example, some methods made input gestures short and small (e.g., electromyographic based inputs [7, 8]) to make them less noticeable. Other methods disguised the appearance of input devices (e.g., a ring-like device [2]) so users could pretend not to interact with any device. Although such methods can enable subtle interaction, users' writing performance is largely limited by the use of gestural inputs compared to the use of physical keyboards.

In this paper, we present *CloakingNote*, a novel desktop interface for subtle writing. We took an idea from a common practice in magic, called misdirection [16]. Misdirection is a principle used to draw the audiences' attention away from magicians' tricks. A flame thrown from a magician's hand, for example, strongly distracts the audience and keep them from seeing the secret tricks that take place simultaneously. Similarly, in *CloakingNote*, a prominent decoy text directs observers' attention away from a real input text. As a result, users can pretend to write a text related to their assigned work (decoy text) while actually writing a more personal one such as a message or an email (real text) (Fig. 1).

To demonstrate the idea behind *CloakingNote*, we present a use scenario in which a fictitious office worker, John, is working in an open and crowded office. He is currently assigned to write a report on a recent meeting. Meanwhile, he receives a personal email from his friend that he has to respond soon. However, he does not want others to notice that he is doing personal things at work. Thus, he opens *CloakingNote* on his desktop and properly adjusts text fields for the real and decoy texts to pretend to continue working on the report while he actually writes the reply at the corner of the screen. As he believes that the content of the reply as well as his intention to hide is less detectable to others, he can write the reply more confidently and efficiently. After he replies to his friend's email, he closes *CloakingNote* and continues working on the report.

RELATED WORK

We review most relevant studies that either support subtle interaction or address the shoulder-surfing problem.

Subtle Interaction Methods

Some research focused on making interactions imperceptible to others, hence *subtle interaction*. Most of the previous subtle input interfaces put emphasis on minimizing the size and duration of input gestures to lessen the possibility of being detected [7, 8, 24], or disguising an appearance of input devices so that even if observers detect the users' gestural motions, they would believe that the users are not interacting with any device [2, 3, 29].

Costanza et al. [7, 8] and Sumitomo et al. [24] proposed body-worn devices that detect either electromyographic signals or abdominal circumferences to make their input gestures "motionless." BackTap [29] detects four distinct taps from the backside of a smartphone so that users can interact subtly by tapping on the pocket in which the device is stored in. Nenya [2] is a finger-worn sensor that looks just like a regular ring but sends magnetic signals to another device (i.e., a wrist-worn device) for identifying the ring's rotation. Perhaps the most relevant and inspiring work was done by Anderson et al. [3], in which they presented a modular set of subtle input and output interfaces. Although performance or usability of their writing method can be limited with the use of gestural motions, the principles behind the subtle interface derived from magic practices inspired us in designing a subtle writing interface.

Some tools disguised appearances of interfaces to make secret reading imperceptible to others. For example, to read social news sites (e.g., Reddit) in workplaces, the sites are disguised as a work-related interface such as MS Outlook [20], MS Word [21], The New York Times website [26], or source code editor [6]. Although we concentrated on writing rather than reading, these tools are similar to our work in terms of disguising their appearances to deceive observers.

Shoulder-Surfing Resistant Input Interfaces

Most previous input methods for alleviating the shoulder-surfing problem hide input texts from both the user and the observers. Therefore, they are suitable only for acquiring short inputs (< 20 letters) from users, such as passwords for ATMs [9, 12, 13, 17] or mobile phones [14]. More relevant to our work is that of Luca et al.'s work [10] in which they placed a real mouse cursor in the midst of multiple dummy cursors that constantly move across the screen. This work can be considered a type of misdirection that hides a real action behind the unrelated but much more prominent distractors. However, displaying a swarm of dummy cursors can easily be seen as an act of concealing the user's actual task because of the unusual pattern on the screen. Therefore, instead of amplifying the noise, we made the input text subtle while presenting the decoy text.

Shoulder-Surfing Resistant Reading Interfaces

Some methods visually block sensitive texts on a screen while showing them on a separate mobile device [5, 22]. Brudy et al. [4] developed a way to detect an observer's position behind a user using a large public display and darken the part of the screen not occluded by the user's body. As a result, every part of the screen becomes invisible to the observer. Another method uses a privacy film (e.g., [1]) that shows or hides a screen depending on different viewing angles, but it requires additional material/devices. Kim et al. [15] presented an LCD screen that can show two independent views at different viewing angles. This method does not require hardware modification but is restricted to a particular type of LCD screen. Moreover, the viewing-angle approaches become weak if observers look at the screen over the user's shoulder at a similar visual angle.

CLOAKINGNOTE

A target use case of *CloakingNote* is writing short and personal texts (e.g., message, email, or diary) in the workplace. The use case is derived mainly from a survey [3] that demonstrated users' high demand for writing personal texts (i.e., sending a message/email or updating Facebook/Twitter) in the workplace, which was prohibited for several reasons (e.g., restriction by employers or social norms). We focus our work on defending against *casual shoulder-surfing*: When a user is writing, employers or colleagues occasionally stand near or behind the user and peep at the computer screen. Therefore, it is not the focus of this work to defend against system-wise monitoring methods such as firewall or system/admin tools.

To support the use case, we chose two design goals: *subtlety* and *reasonable writing performance*. By *subtlety*, we mean not only making the input text subtle, but also hiding the use of the subtle interface itself. Therefore, users can protect their private texts from others (thus alleviating the shoulder-surfing problem) as well as write the texts more confidently. Next, because adopting gestural motions as in subtle interfaces [2, 3, 7, 8, 24, 29] often sacrificed users' input performance, we used typical keyboards to achieve better performance. Because many people are already familiar with keyboards, we believe most desktop users can benefit from *CloakingNote* without buying additional devices or learning new gestures.

The prototype of *CloakingNote* consists of two windows, one for the real text and one for the decoy text. By using the windows, users can customize each text (e.g., change a font size; Fig. 2). After the customization, both windows become transparent, float above other windows, and render letters one by one upon users' keyboard press (Fig. 3). For this prototype, we focused on the technique (i.e., subtle writing) itself rather than adding more functionalities; the current implementation is not integrated with specific websites or

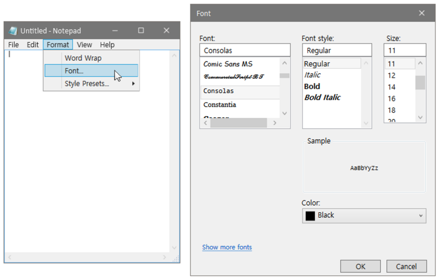


Figure 2. The customization window of the decoy text.

apps such as Facebook so that it is currently not able to send or upload written texts to anywhere.

In designing *CloakingNote*, we considered the four design guidelines for subtle interfaces [3]—*simulation and dissimulation*, *separating cause and effect*, *modularity*, and *user customization*—as follows:

Simulation and dissimulation Whereas simulation disguises something to make it appear to be something else, dissimulation disguises it to make it appear not to be what it truly is [3]. Accordingly, *CloakingNote* adopts a decoy text (Fig. 1B) to convince observers that a user is writing something else instead of his/her real text. To imitate the real text, *CloakingNote* renders the decoy text character by character each time the user types a key. This means that no matter which key is pressed, predetermined letters appear in the decoy. However, we treat a backspace key differently. If observers saw the user press the backspace key but noticed that the decoy text typed, they would become suspicious. Thus, we let the backspace reacts as it does (i.e., remove the last letter from the decoy text). In addition, we decided to make the real text less prominent by using smaller font and lower luminance contrast with its background (Fig. 1A).

CloakingNote supports subtlety not only in writing but also in preparing to use *CloakingNote*. For such support, we disguised the customization windows of the real and decoy texts to look just like a common writing interface, Windows Notepad (Fig. 2). As a result, even if observers see the user setting up *CloakingNote*, they might think that the user is using Notepad instead of *CloakingNote*.

Separating cause and effect By separating an action and its effect, we can make observers believe that the effect is not an outcome of the action [3]. For example, rendering a real text with a delay (i.e., temporal separation) could misdirect observers to believe that the text is not being written by the user. If the real text is rendered in the middle of a webpage with a delay, observers might think that it is just animated content inside of the webpage (e.g., an online advertisement). However, this delayed real text can significantly reduce users' writing performance. Therefore, rather than temporal separation, we opted to use spatial separation to misdirect observers. We separated the area in which the real text is typed from the observers' expected writing area. For example, if observers witnessed a user typing on a keyboard and a decoy text being rendered on a common writing interface (e.g., MS Word), they might think that the user is writing the decoy. In contrast, it would be much more difficult for them to notice the isolated real text.

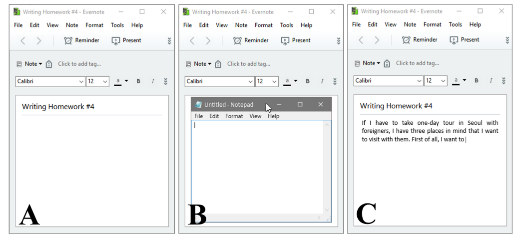


Figure 3. Disguising the decoy text. (A) Users choose a writing interface (e.g., Evernote). (B) They customize the text to make it suitable for the interface. (C) When they start to write the real text, the customization window becomes invisible.

Modularity Because repeated use of the same trick might eventually lead observers to notice a secret action, a subtle interface should allow users to alter the position and appearance of secret interaction to maintain its subtlety [3]. With *CloakingNote*, observers may become suspicious if the decoy text always appears on the same writing interface. Therefore, we allow users to choose the writing interface they pretend to use. Moreover, users can customize the size and position of a decoy text rendering area to make it suitable for a specific writing interface (e.g., Evernote; Fig. 3). Users can also change the appearance (e.g., font, color, and size) of the decoy text to make it match the chosen interface well. For example, to pretend to write on Windows Notepad, users can overlay the decoy text on it and use its default style (e.g., Consolas with a size of 11px). Similar to the decoy, users can tune the appearance of the real text—font, color, and size—as well as its position, making it less noticeable.

If the customization phase took too much time and efforts, it would be impractical to use *CloakingNote* for writing short texts. To make customization quicker and more convenient, *CloakingNote* provides presets, which include style presets (e.g., "Research Paper," which uses Times New Roman with a size of 10px) and size/position presets (e.g., "MS Word - Right Half" for overlaying the decoy text on MS Word that is positioned on the right half of the screen).

User customization Subtle interfaces should let users customize it according to their contexts [3]. *CloakingNote* also supports customization to encompass users' various contexts. If a user, for example, is a graduate student who works at a laboratory, he/she may use a research paper as a decoy text while actually sending private messages to his/her friends. In this scenario, the user can overlay a decoy text on a word processor and adjust the appearance properly before using *CloakingNote*. In addition, *CloakingNote* allows users to select the content of the decoy text so it is relevant to what they pretend to write. In the example above, the user can take texts from his/her drafts to pretend to work on them (Fig. 4A).

EXPERIMENT 1: SUBTLETY TEST

We conducted a controlled user study to assess the subtlety of *CloakingNote*. The subtlety was assessed against two factors: (1) Contrast - contrast level between the real text and its background and (2) Stimulus - content of the decoy text.

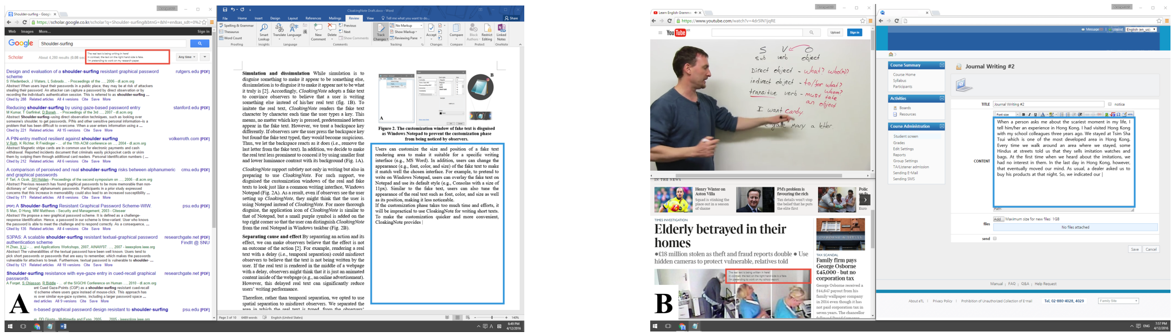


Figure 4. The participants of qualitative study freely changed the layout of *CloakingNote*. (A) One participant pretended to work on her research paper. (B) Another used online submission system to pretend to write his school report. The real and decoy texts are highlighted with red and blue rectangles, respectively. Both examples are reproduced for the anonymity.

Participants We recruited 36 people (12 female) from a university, ages 20 to 31 years with normal or corrected-to-normal vision (20/25). We checked for participants' visual acuity and color-blindness with standard pseudoisochromatic plates. They all were native Korean speakers and received about $10 for their participation.

Apparatus We used a 23-inch monitor with a screen resolution of 1920x1080 (Samsung SyncMaster S23B350T). The contrast value of the monitor was controlled using DataColor's Spyder 3 Pro.

Design We used two between-subjects factors of Contrast (i.e., low-, mid-, and high-contrast) and Stimulus (i.e., IT, sports, and movie). We measured noticeability which was the number of sessions a participant took to find the real text as a dependent variable. A trained actor (one of the authors) pretended to be writing a decoy text using Microsoft Word in a room while actually using *CloakingNote* to write the lyrics of the Korean national anthem that all participants are expected to know. To maintain a consistent performance across all sessions, the actor wrote the same real text (i.e., Korean national anthem) in all sessions. Participants did not have any previous knowledge of what the actor was actually doing. We told them that the experiment was about how interruption affects task performance and they were the ones who would interrupt the other person (i.e., the actor).

As human visual search performance is highly related to object-background contrast ratio [18, 25, 28], we decided to assess the subtlety of *CloakingNote* in terms of contrast ratios between the real text and its background. We chose three contrast levels: high = 11:1 for optimal ratio for visual acuity [18], mid = 3:1 for minimum ratio for providing a proper display quality [25], and low = 1.5:1 for a lower level than the minimum ratio.

The screen layout was fixed across all conditions for all users (Fig. 1). On the right, we overlaid a decoy text (i.e., an essay) inside MS Word. On the left, we showed a webpage whose content was related to that of the decoy text. The layout of the webpage (e.g., the position and size of pictures and texts) was modified to be identical across all conditions. The real text was overlaid inside of the webpage. We placed the real and decoy texts away from each other (i.e., the real text on the left bottom part of the screen and the decoy text on the right) to make the real text less noticeable [18, 23]. Note that participants stood behind the actor's right shoulder. To ensure that *CloakingNote* is effective regardless of the fake content (i.e., the contents of the decoy text and the webpage), the content was varied depending on the stimulus condition. We selected the top news categories (i.e., IT, sports, movie) from CNN (i.e., cnn.com), excluding political ones.

The purposes of observation can be diverse in real-world scenarios. For example, one person may approach a user for a simple task (e.g., ask a question) whereas another (e.g., employer) may try to see whether the user is doing an assigned task or not. To see how the purpose of observation affects the subtlety of *CloakingNote*, we introduced a within-subject factor—participant's knowledge level—and changed it every three sessions (i.e., three levels).

Procedure After signing a consent form and pre-study questionnaire, participants were briefly introduced to the overall procedure and tasks for about five minutes, then started study sessions. In each session, participants were asked to enter the room and stand behind the actor's right shoulder. Then, they had to carry out two tasks. First, they had to ask the actor a question. The questions were given to participants one at a time before they enter the room, and they were related to the content of the decoy text (e.g., "What are you writing about?" or "When was the movie released?"). Second, they had to observe what the actor was doing. These two tasks reflect the real-world scenarios in which one person approaches the other working at a computer and engages in a conversation. After 30 seconds, we knocked on the door to signal participants to leave the room and report the answer to the question as well as their observations. We repeated the session until the participants either noticed what the actor was really doing or completed nine sessions.

For the first three sessions, participants observed the actor without any knowledge of the concealment (no-knowledge level). For the next three sessions, we told them to look out for any suspicious activity that the actor might be engaged in using a computer (suspicion-knowledge level). For the last three sessions, we told them to report if they found the actor doing something other than writing a text on a word processor (awareness-knowledge level).

Upon their completion of all sessions (nine at most), we interviewed them for subjective feedback. At the interview, we first asked them if they had tried writing subtly in their everyday lives and how they did if they had. In addition, we asked them how they noticed that the actor was doing something else. The entire study took about an hour per participant.

RESULTS & DISCUSSION

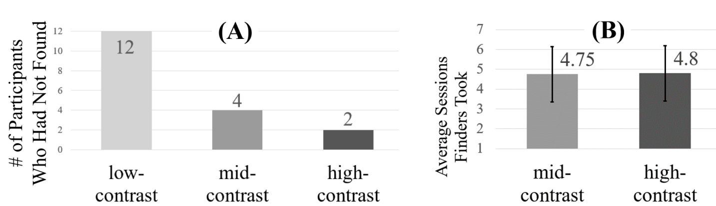
Eighteen participants (out of 36) successfully identified the real text (hereafter "finders"). Chi-square tests on Contrast and Stimulus revealed a significant main effect of Contrast ($\chi^2(2) = 18.68$, $p < .001$) on noticeability (Fig. 5A). Post hoc testing showed that low-contrast real text was significantly less noticeable than mid- and high-contrast ($p < .001$). We could not find a significant effect of Contrast on the Knowledge level at which the 18 finders found the real text (Fig. 5B).

During the interview, most participants (33 out of 36) reported that they personally had attempted to write subtly. They commonly reported it occurring during social activities (e.g., writing text messages or emails) or private work (e.g., writing a resume, diary, or essay). In addition, about half of the participants (17 out of 36) encountered the situation even while doing professional work (e.g., writing a report or paper) that contained little private information. One participant said, "*I feel uncomfortable about showing my incomplete work to others. It's like my 'diary' is being exposed to them.*" (P27).

We investigated their various techniques for subtle interaction and identified several limitations among them. The most common techniques were *closing or switching a current app to another* upon detecting others approaching (17 participants) and *turning the screen away from other's sight* (11 participants). However, they said that such techniques were often noticed by others, and they become embarrassed. One said, "*I tried to hide my essay from my mother by switching to another application. However, she noticed me hiding something and said 'What are you hiding in such a hurry?'. Hearing it, I felt as if I were doing something improper things with my computer.*" (P35). Accordingly, most participants (30 out of 36) said that they wanted to conceal even their intention to hide from nearby people while writing texts. Some used even inefficient techniques, such as *stop writing* until nobody is around (12 participants) or *moving to another place* where he/she can be alone (2 participants). Participants said that these strategies had a negative influence on their writings. "*When I resume writing later, the end result is not as good as I hoped for. I end up forgetting some important ideas while moving or waiting for others to leave.*" (P34).

We asked the finders how they were able to recognize the real text. Sixteen participants responded that the real text being rendered in an unexpected place on the screen attracted their attention. The other two finders replied that the unnatural typing speed of the decoy text led to suspicion, which eventually resulted in them detecting the real text. Such suspicion was derived from the difference in contents between the real and decoy texts (i.e., an essay for the decoy and lyrics of the Korean national anthem for the real). Because writing an essay requires writers to contemplate, it is likely to be written more slowly than lyrics would be. Because the actor wrote the lyrics while observers saw the essay being rendered, the finders recognized that the essay was being written unnaturally faster than what they would have thought was possible. Before the study, we thought of other clues such as the mismatch between pressed keys on a keyboard and input characters, or the discordant typing rhythms between the real and decoy texts (i.e., typing may awkwardly pause in the middle of a word or a sentence in the decoy text). However, no finders reported such discrepancies. One mentioned, "*To confirm which text is being written by the [writer], I tried to compare between typing keystroke positions and input characters. But it was impossible, because I couldn't observe both at once.*" (P25). This demonstrates that visual subtlety of the real text is much more important than resolving the incomplete disguise of the decoy text.

The results (Fig. 5C) revealed that *CloakingNote* was highly subtle under the low-contrast condition (all unidentified). Moreover, only four participants (11%) identified the real text during the first three sessions (the total duration of the three sessions was 90 secs), implying a low chance of being caught during a short period. Twenty-one participants (58%) did not identify the real text even when they knew that the writer might be engaged in suspicious activities (suspicion-knowledge level). Moreover, only five finders noticed the content of the real text (i.e., the lyrics for the Korean national anthem), showing that it was much more difficult for observers to grasp the private contents of users' texts than find users' secret activities. Overall, results suggested that *CloakingNote* successfully hides the content of secret writing as well as the use of the interface itself.



(C)	no-knowledge			suspicion-knowledge			awareness-knowledge		
	1	2	3	4	5	6	7	8	9
low-contrast	0	0	0	0	0	0	0	0	0
mid-contrast	0	0	2	4	5	7	8	8	8
high-contrast	1	1	2	3	7	8	10	10	10

Figure 5. The results of the subtlety test. (A) The number of the participants who had not found the real text during nine sessions. (B) Mean number of sessions the finders took to identify the real text. Error bars denote standard deviation. (C) A heatmap shows the accumulated number of finders for all combinations of knowledge level and contrast ratio.

EXPERIMENT 2: PERFORMANCE TEST

After confirming that the low-contrast text can be effective at hiding its existence in Experiment 1, we hypothesized that there would be a trade-off between the contrast level and users' writing performance; lowering contrast makes the real text more difficult to be perceived from both the observers and writer. To see how the contrast affects the writing performance, we designed a follow-up experiment. We used the same equipment as in the first experiment.

Participants We recruited 18 (six female) participants at a university. They were 20 to 29 years old and had normal or corrected-to-normal vision (20/25). We checked for participants' visual acuity and color-blindness with standard pseudoisochromatic plates. They all were native Korean speakers and received about $10 for their participation.

Design This experiment consisted of two sub parts: quantitative and qualitative evaluations. In the first part, we used two within-subject factors of Configure (i.e., low-, mid-, high-contrast, and baseline) and Stimulus (i.e., IT, sports, and movie). We used the stimulus condition to ensure that the users' writing performance is effective regardless of the fake content. There were two dependent variables: typing speed and accuracy. Our contrast ratios were kept the same as in Experiment 1. In addition, the highest level of contrast (pure black text on a white background) with a font size of 18px was used as the baseline condition. The baseline also let participants enter text in the region where the decoy text would normally appear, which reflects the situation the participant would have been in if *CloakingNote* were not in use. The screen layout was identical to that of the first experiment and fixed across all conditions (Fig. 1).

Procedure After checking visual acuity and color-blindness, participants were introduced to the procedure and tasks for both parts. Each participant completed 12 typing trials (4 Configures x 3 Stimuli). The order of trials was determined using a balanced Latin square. For each trial, participants typed 10 phrases, with a total of 120 phrases per participant. Phrases for each participant were randomly selected from a MacKenzie and Soukoreff phrase set [19] without repetition. Each phrase was shown on top of the typing area until the participant pressed Enter to finish and see the next one. Participants were asked to type each phrase as accurately and quickly as possible.

After the 12 trials were completed, a qualitative evaluation (i.e., in the second session) was conducted by letting participants freely write a short essay for five minutes while an actor peeked over their shoulder three times. First, the participants freely changed the layout of on-screen components up to 10 minutes to arrive at the format they felt adequate for protecting their real text from the observer. They also had to choose their own decoy text. Then, we provided them with a randomly selected writing topic from TOEFL Writing Topics [27]. During the writing, the actor entered the room and observed participants behind their shoulders (for 10, 20, and 30 seconds at the 0.5-, 1-, and 2-minute marks). To provide a realistic experience of shoulder surfing, we told participants that another participant was given a task to find out what they were doing and would come in for observation. Once all sessions were finished, we surveyed the participants using a 7-point Likert scale questionnaire. The entire study took about an hour per participant.

RESULTS

Typing performance was assessed using two measures: character per second (CPS) and character error rate (CER). To calculate CPS, we defined the typing time of each phrase as the time interval between the first character input and an Enter key press. CER was defined as the Damerau-Levenshtein distance between presented and typed phrases divided by the length of the presented phrase.

Using an RM-ANOVA, we analyzed the typing performance in terms of Configure and Stimulus. The analyses demonstrated the main effect of Configure on CPS ($F_{3,51}$ = 11.7, p < .01). Post hoc analysis revealed that typing was significantly slower in low-contrast (M = 5.1 cps) than high-contrast (M = 5.4 cps) and baseline conditions (M = 5.5 cps; p < .01 for both), although the mean performance degradation was only 5.6%. We could not find a significant effect of Configure on CER ($F_{3,51} = 1.0$, ns). In addition, we could not find any significant effect of Stimulus (i.e., IT, sports, and movie) on both CPS and CER.

During the second session, we investigated participants' layout strategies for hiding the real text. We characterized their interesting strategies into three categories.

Foreground-match Strategy Six participants placed the real text in a contextually meaningful position, so that it seemed as if it initially belonged to the context. For example, one participant put the real text below a picture to disguise it as a caption for the picture. Another aligned the real text next to the end of another text and changed the font and size of the text to make it look like the surrounding text (Fig. 6A).

Background-match Strategy Six participants laid the real text in places where the presence of text is not normally expected. Then, they customized the real text so the background had a protective appearance. One participant laid the real text behind Windows' semi-transparent taskbar and adjusted the luminance value of the real text (Fig. 6B). Another participant put the real text in the middle of a picture.

Distractive Strategy Five participants put various components on the screen to distract an observer's attention away from the real text. Some displayed three windows in the screen that consisted of texts, pictures, or even videos. For even stronger distraction, two participants turned on the sound while a video was being played (Fig. 6C). One participant had strong confidence in the strategy: "*I could focus only on my writing enough not to notice the [observer] approaching, because I supposed that the observer wouldn't ever noticed my [real text]*." (P49).

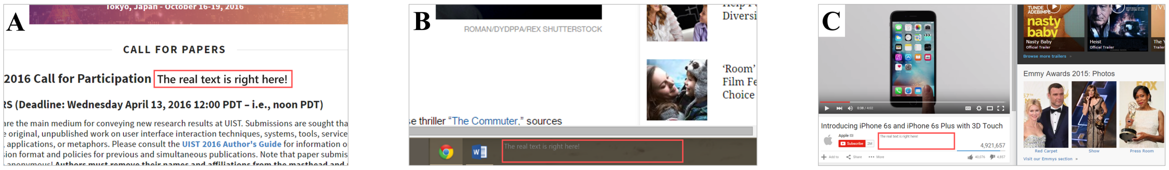


Figure 6. We categorized participants' layout strategies as (A) foreground-match, (B) background-match, and (C) distractive strategies. The real texts are highlighted with red-bordered rectangles.

According to the questionnaire results, *CloakingNote* was fun to use (mode of 7 out of 7), useful (5), and easy to use (5). Moreover, they felt comfortable (5) and confident that *CloakingNote* protected their information (6) while an actor observed. They also reported that they would use *CloakingNote* in the future (6).

DISCUSSION

Our two studies showed that *CloakingNote* was effective in hiding the real text in low contrast and it could be used with only minor performance degradation. In this section, we discuss results of the studies in terms of users' layout strategies, training overhead, and trade-off between subtlety and writing performance. In addition, we discuss extending *CloakingNote* to other devices and other types of interaction.

Layout Strategies

We considered the contrast as an important factor for subtlety. However, the contrast became less crucial for participants who used the foreground-match strategy because they tried to make the real text have a contextual appearance using high contrast ratio. However, because the real text in *CloakingNote* changes as a user types, such high saliency (e.g., high contrast ratio) could lead observers to spot the real text. To better support the foreground-match strategy, it is necessary to minimize the temporal visual changes of the real text. One solution can be overtyping the real text on prepared dummy texts rather than writing it on an empty space. In contrast, the background-match strategy seems the most successful strategy in terms of subtlety as it places the real text in a less expected area (e.g., behind Windows' semi-transparent taskbar). However, it seems inevitable that the background-match strategy provides worse writing performance than do other strategies because it uses lower contrast to make the real text subtle.

Because the foreground- and background-match try to make the real text harmonize well with its surroundings, the appearance and size of the real text had to be considered in light of its surroundings. In contrast, the distractive strategy adopts compelling fake contents while leaving the real text as it is, so the distractive strategy allows wider design choices in customizing the real text. For example, a user can write the real text on a pure white background without sacrificing writing performance while fake content distracts observers.

Overall, participants reported that they had fun using *CloakingNote* (mode of 7 out of 7), especially when making their own layout strategy. They mostly envisioned scenarios from their lives, and developed their strategy targeting those scenarios. One participant (P42), who was a graduate student, said that she pretended to be in her laboratory and tried to deceive her advisor by pretending to work on her research paper. To do so, she used her draft as the decoy text and presented Google Scholar's search results to pretend to find references (Fig. 4A). Another participant (P50), who was an undergraduate student, pretended to write a school report using an online submission system and watch a related lecture video at the same time (Fig. 4B).

Training Overhead

Participants, in general, felt comfortable using *CloakingNote* while an actor observed (mode of 5 out of 7) their secret writing. A few participants (4 out of 18) reported that they were concerned that the mismatch between the pressed keys and decoy texts would make the observer suspicious of their writings. However, according to the interviews in the first experiment, such discrepancies were in fact hard for observers to notice. When we informed participants of such results, they commonly said that if they had known those results in advance, they would have used *CloakingNote* more confidently. However, one commented that he might need longer training time (e.g., more than a few minutes) to become confident using *CloakingNote* in front of others. This finding was consistent with the guidelines for subtle interaction [3], which put emphasis on user training.

Subtlety vs. Writing Performance

The results of two user studies revealed the solid trade-off between subtlety and writing performance. The lowest contrast ratio (i.e., 1.5:1) provided the highest subtlety at the cost of performance degradation; in contrast, the highest contrast ratio (i.e., 11:1) yielded the best performance with less subtlety. Therefore, the contrast ratio can be chosen depending on the sensitivity level of the real text. In the second experiment, for example, because the participants were asked to write personal thoughts (i.e., essay), 50% of the participants sacrificed their writing performance by choosing a contrast ratio lower than 1.5:1 for the real text.

Extending *CloakingNote* to Other Types of Devices

In Experiment 1, eight participants mentioned that they commonly had attempted to write subtly even when using mobile devices (e.g., smartphones and tablets). *CloakingNote* can be extended to support the mobile devices, but some challenges may result from the limited screen space. First, the mismatch between the decoy text and the keyboard press might affect the subtlety of our technique because the decoy might have to be placed much nearer to a (software) keyboard than in the desktops. Therefore, it is necessary to find out to what extent observers can recognize such mismatch. Second, some of the layout strategies might not be suitable to use. With mobile devices, it is hard to isolate the real text from the decoy due to the limited screen space. As a result, even if the real text has a protective appearance with its background (i.e., using background-match), observers might be able to spot the real text when they watch the decoy. The distractive strategy might not be suitable as well because diverse distractive contents (e.g., videos) cannot be used at once. Instead, disguising the real text as a common text element of the mobile devices (e.g., text entry suggestions in soft keyboards) seems a more appropriate approach (i.e., the foreground-match). Because a small discrepancy between the real text and its disguising object could make observers suspicious, thoroughly disguising the real text seems crucial for successful subtle writing on mobile devices.

CloakingNote can be also extended to public displays to address the shoulder-surfing problem in writing private texts. As screen size of the public displays is normally larger than that of the mobile devices, the mismatch between the decoy text and pressed keys as well as using the distractive or background-match strategies might not highly hamper the subtlety of our technique. However, the public displays are usually installed in a crowded space with good accessibility for passers-by so many more people can observe the screen at once. Therefore, the observers might be able to notice a user using *CloakingNote* with less time than in desktops.

Extending *CloakingNote* to Other Types of Interaction

The idea of *CloakingNote* can be used to support subtlety in other types of interaction. For example, according to a survey result [11], social awkwardness was one of the main reasons for not using Android's Face Unlock (i.e., biometric authentication system): *"I feel like I'm taking selfies all day!"*. To address the awkwardness, we can apply our layout strategies to the authentication system. For example, using the background-match strategy, a user can pretend not to take a selfie; a prominent webpage (decoy) can be shown in the screen while dimmed user's face (real) can be shown in the corner. The user can also pretend to take a picture of a scenic view rather than his/her face; the view being taken by the back camera can be shown in full-screen mode while the dimmed user's face can be shown in the corner.

We can also imagine video-watching interaction using foreground-match strategy; an online video lecture (decoy) can be played in the center of the screen while a cartoon (real) is disguised as a video advertisement on the side. We can further use one of the design guidelines [3] (i.e., separating cause and effect) to support user interaction; when a user rewinds the decoy video, it reacts immediately whereas the real one reacts with a delay (i.e., temporal separation).

LIMITATIONS AND FUTURE WORK

Costs of Using *CloakingNote*

The use of *CloakingNote* involves spatial and temporal costs. First, a small portion of the screen space needs to be occupied by the decoy text (i.e., spatial cost). However, as we targeted writing short texts (e.g., emails), which do not normally require large space to work on, we believe that the modest space is a reasonable cost for achieving subtlety. Second, setup time is required before using *CloakingNote* (i.e., temporal cost). To shorten the setup phase, we provided various customization presets (e.g., "Research Paper" style preset). In Experiment 2, about two-thirds of the participants spent the entire 10 minutes finding a creative setup, but others made quick decisions (about 10−20 seconds) by utilizing the presets provided. If users could save their setups as presets for future use, the setup time could be shortened significantly even for the creative participants. Going one step further, we would be able to build *CloakingNote* as a plugin for existing writing interfaces (e.g., Gmail) to further reduce the setup time. To evaluate the feasibility of the setup phase in real world scenarios, it would be also worth measuring the actual setup time as well as the amount of effort users are willing to make.

When *CloakingNote* Becomes Well-known

As we provide many configurable parameters in *CloakingNote* (e.g., choosing a writing interface to pretend to use), we think that users still have chances to find subtle setups even when the system becomes well-known. However, because we did not include a "customization knowledge" condition as in [3] (i.e., letting participants know about *CloakingNote* in advance of the observations) in Experiment 1, our study results did not verify whether *CloakingNote* was effective with the knowing observers.

In Experiment 1, we focused on assessing the subtlety of *CloakingNote* in writing, but not in preparing (i.e., the actor customized the real and decoy texts before each participant started to observe). As the setup phase can also affect the subtlety of *CloakingNote* in real-world scenarios, it would be worth assessing the subtlety of the setup phase as well. Because writing personal texts to communicate with other people usually requires users to read received texts sent from the others, it would be also valuable to support both the writing and reading interaction in the future. Future work may also include assessing subtlety with additional visual parameters such as the font size and position of the real text.

CONCLUSION

We presented *CloakingNote*, a novel desktop interface for subtle writing. Through two controlled experiments, we found *CloakingNote* is effective in hiding users' personal texts as well as the interface itself with minor performance degradation. In addition, we categorized and discussed some of the users' interesting layout strategies such as the foreground-match, background-match, and distractive strategies.

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