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# The Distracting Effects of a Ringing Cell Phone: An Investigation of the Laboratory and the Classroom Setting

**Jill T. Shelton**, **Emily M. Elliott**, **Sharon D. Lynn**, and **Amanda L. Exner**
Louisiana State University

## Abstract

The detrimental effects of a ringing phone on cognitive performance were investigated in four experiments. In Experiments 1 and 2, the effects of different types of sounds (a standard cell phone ring, irrelevant tones and an instrumental song commonly encountered by participants) on performance were examined. In Experiment 1, slower responses were observed in all auditory groups relative to a silence condition, but participants in the ring and song conditions recovered more slowly. In Experiment 2, participants who were warned about the potential for distraction recovered more quickly, suggesting a benefit of this prior knowledge. This investigation continued in a college classroom setting (Experiments 3a and 3b); students were exposed to a ringing cell phone during the lecture. Performance on a surprise quiz revealed low accuracy rates on material presented while the phone was ringing. These findings offer insight into top-down cognitive processes that moderate involuntary orienting responses associated with a common stimulus encountered in the environment.

### Keywords

auditory distraction; cell phone; irrelevant sounds

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With the estimated number of cell phone users in the U.S. exceeding 262 million (CTIA International Wireless Association, 2008), the growing prevalence of cell phones in daily life has generated interest in research on this topic. Recent research has focused on the detrimental effects of cell phone conversations on driving performance (Strayer & Johnston, 2001; Strayer, Drews, & Johnston, 2003; Strayer, Drews, & Crouch, 2006), leading to the conclusion that the attentional resources drawn away from the driving field can lead to poor driving performance. However, research has not addressed the potential distracting effects of the cell phone ring itself. There were two primary goals for the present research. First, we were interested in better understanding the cognitive response to a cell phone ring by assessing the temporal nature of the distraction and by isolating the cognitive factors associated with this distraction. The second aim was to evaluate how this commonly encountered noise in the environment would affect performance on real-world activities.

Research has demonstrated that only a limited amount of information can be attended to at any given moment, and the content of this information is determined by either a voluntary

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Address correspondence to: Jill Shelton, Department of Psychology, Campus Box 1125, Washington University, Saint Louis, MO 63130, Phone: (314)935-7610, Fax: (314)935-7588, jshelton@artsci.wustl.edu.

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attentional control process or an involuntary orienting response (Cowan, 1995). In support of the role of voluntary attentional control processes, the cognitive response to a ringing cell phone may be similar to the costs observed when individuals engage in cell phone conversations. For example, cell phone conversations were shown to disrupt performance on a secondary task, and the authors concluded that the conversations required voluntary attentional control processes that recruited resources from other ongoing activities (Strayer & Johnson, 2001). In this case, central executive resources were used by the cognitive system to attend to a chosen set of information (Cowan, 1995).

Alternatively, the response to a ringing cell phone may be primarily associated with an involuntary orienting response that is characterized by a brief distraction from ongoing activity. Indeed, previous research revealed that the presence of novel sounds in the environment led to delayed responses to an ongoing visual activity (Escera, Alho, Winkler, & Näätänen, 1998). In this situation, attentional resources were re-allocated due to an individual's involuntary response to new incoming information. This orienting process is often elicited by novelty being introduced into the environment or as a result of changes in the existing situation (Cowan, 1995). For example, the sudden onset of a new sound in the environment, such as a ringing phone, could automatically recruit attentional resources from other ongoing activity. This view of attentional orienting was based upon the orienting reflex theory of Sokolov (1963), in which a neural model of a stimulus is built and subsequent stimuli are compared to the neural model. When a match occurs, no further response is needed; however, in the case of a mismatch, the orienting response occurs. This can include physiological changes such as decreased heart rate and eye movements, as well as a shift of attention toward the new or changed stimulus.

While past studies have demonstrated that both voluntary and involuntary shifts in attention can hinder performance on ongoing cognitive tasks, the present view is that the response to a ringing cell phone in the environment is more likely associated with an involuntary attentional orienting response than a voluntary attentional control process. This is based on the assumption that cell phone rings typically cause problems in everyday life in which people are trying to execute specific goals, such as listening to a lecture in the classroom. In this situation, attentional resources may initially be oriented to the incoming sound, but unlike the situation where attentional control resources are used to engage in a phone conversation, after being distracted by a ringing cell phone an individual will re-direct attentional resources back to the original ongoing activity.

There are, however, conditions in which the response to a ringing cell phone would elicit top-down attentional control processes that may moderate the involuntary orienting response. For example, many people use popular songs as their ringtones, and an individual's familiarity with an incoming sound could result in their attention being sustained towards the ring for a longer period (e.g., imagining the lyrics that correspond with that particular melody). Additionally, if an individual is expecting a phone call then top-down processes could also influence their response to an incoming cell phone ring. It is unclear if a ringing cell phone will cause a brief distraction, comparable to an attentional orienting response, or if a more sustained distraction effect will occur. Based on the preceding argument, we predict that the presence of a ringing cell phone in the environment will elicit an involuntary attentional orienting response; however, top-down attentional control processes could moderate this response in certain situations. To distinguish between these two views of attentional distraction, it is important to assess the time course of the response to the ringing cell phone; therefore, a task that allowed for trial-level response time analysis was used in the first two experiments. In addition, we investigated several factors that might contribute to the severity of negative effects resulting from this type of auditory distraction, such as the different types of ringing sounds (e.g., a ring tone; Experiment 1) and the presence of a warning (Experiment 2). By including these manipulations, we hoped to assess the role of both voluntary and involuntary attentional processes.

The second objective was to examine how the presence of cell phone rings influence peoples' behavior in real-world environments. Past research has investigated the distracting effect of various other auditory stimuli, such as irrelevant speech and sounds in real-world settings (for a review, see Beaman, 2005). For example, Banbury and Berry (1998) noted that office noise has been consistently reported as the greatest annoyance in workplace environments. To examine this issue, they conducted three experiments in which participants completed activities comparable to those carried out in the workplace (mental arithmetic and memory for prose) while listening to speech or other sounds typically occurring in an office setting. The sound condition consisted of office recordings such as fax machines, printers, and telephone rings, while the speech condition consisted of these noises along with conversations by other workers. The results revealed that office noise plus speech significantly disrupted performance in both the memory for prose and mental arithmetic activities when compared to a silence condition, while the office noise only condition led to disruptions in mental arithmetic but not prose memory. These findings demonstrated the detrimental effects of auditory distractions in the workplace, but were not discussed in terms of attentional orienting.

It is, therefore, important to investigate the cognitive consequences of a sound that commonly occurs in our everyday lives, a ringing cell phone. The goal of Experiments 3a and 3b was to extend findings on attentional distraction found in the first two experiments to determine whether the presence of a ringing cell phone in a real-world setting (e.g., a college classroom) would be detrimental to cognitive performance. We chose a college classroom for our real-world setting because it provides an example of an everyday situation where people are trying to attend to an important ongoing cognitive activity in the face of potential distractions, such as a fellow classmate's ringing phone. Furthermore, the classroom offers an ideal testing situation in which students are naturally trying to acquire knowledge on a given topic that they expect to be tested on at a later point.

## Experiment 1

The purpose of Experiment 1 was to track the response to a phone ring over time. This goal was accomplished by making group comparisons in a lexical decision task in which different auditory distracters were heard by some participants but not by others. The trial-level reaction time (RT) measures allowed us to track the time course of distraction effects and to detect potentially subtle differences among the various auditory conditions. During the experimental block of the task, participants were exposed to a standard cell phone ring (which actually sounded like a ringing phone and was not a series of tones), two irrelevant tones, an instrumental version of a university fight song, or no sound. A university fight song is often the anthem of a given university that promotes their athletic teams. These songs are typically played by the band at collegiate sporting events and are familiar to most students from the university. In fact, many university fight songs can be downloaded and used as the cell phone ring tone.

The design of the present experiment allowed an investigation of whether a cell phone ring would lead to a brief attentional orienting response similar to that produced by other sounds. Different sound conditions were selected to help illuminate the attentional processes driving this distraction effect. If a cell phone ring is categorized by the human information processing system as just another sound, then the particular sound used should not cause differential degrees of distraction. However, if a cell phone ring has particular relevance to our society, then this sound should cause a larger distraction effect relative to the other sounds. To address this question, we chose experimental conditions consisting of sounds that were less frequently encountered in the environment (e.g., tones), a traditional cell phone ring, and sounds that were often encountered by these participants and could potentially be used as a ring tone(e.g., the university fight song). A strict attentional orienting account would predict grater distraction from the most novel sound being introduced into the environment, which in this case was the irrelevant tone sequence. Alternatively, if top-down processes augment the attentional orienting process then sounds that are more familiar to the participants would elicit the largest distraction effect. The first prediction was that slower response latencies would be observed in all three sound conditions relative to the no sound condition. Second, we predicted that participants would recover more quickly in the face of irrelevant sounds (e.g., tones) than if exposed to a phone ring or the fight song. Additionally, we predicted that the university fight song would lead to a more sustained disruption than a traditional ringtone. If the latter hypothesis is supported, it would suggest that existing knowledge can supplement the otherwise involuntary orienting response to distracting sounds in the environment. Evidence for this hypothesis comes from electrophysiological data; a distinct pattern of ERP data was found when a personal ringtone was used, as compared to another person's ringtone (Roye, Jacobsen, & Schröger, 2007).

# Method

## Participants

After screening out participants who reported hearing loss or who did not speak English as their native language, the following groups of participants were included in the data analyses: control (n= 44, female = 28); tone (n= 36, female = 28); ring (n = 38, female = 26); and song (n = 40, female =31). These 158 participants were recruited from Louisiana State University Psychology courses and received either course credit or extra credit in return.

## Materials/Procedure

Participants filled out informed consent forms and provided demographic information before completing the lexical decision task. This task was presented using E-Prime software (Schneider, Eschman, & Zuccolotto, 2002). In this task, pairs of stimuli were presented and consisted of words and non-words, with one presented 25 mm above the central fixation point and one 25 mm below this point. The fixation cross appeared on the screen for 1000 ms, followed by the presentation of each pair of stimuli. The stimulus pair remained on the screen until the participants responded or for ten seconds if a response was not made. There were four different types of pairs presented: 1) word, word; 2) non-word, non-word; 3) word, non-word; and 4) non-word, word. The words used for this task were generated from the MRC Psycholinguistic Database (Coltheart, 1981), and non-words were generated from the ARC Non-word database (Rastle, Harrington, & Coltheart, 2002). The words were generated according to the following criteria: one-syllable nouns, four to five letters, and with average familiarity and concreteness ratings that ranged from 400 to 600. The criteria for non-word generation were: one-syllable, four to five letters, and orthographically existing onsets and bodies. Sixty words and sixty non-words were used to construct the task stimuli. The words were presented in 18 point Courier New font, with each word measuring 7 mm in height on the computer screen and between 25 and 35 mm in length (depending on the number of letters in the word).

Participants were instructed, via written instructions on the computer screen, to press 1 on the keyboard if both stimuli were words and to press 2 otherwise. They were asked to respond as quickly as possible. After a response was recorded, the fixation cross immediately appeared for the next trial. Participants completed eight practice trials followed

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by three blocks of test trials. The order of presentation of the trial types was randomly determined for each participant within each block. Each block of test trials contained 20 trials, equally divided among the four trial types. There was no indicator of the block separation to the participants; the purpose for this separation was to collect RT and accuracy measures before, during, and after the auditory distracters.

Participants completed the study in groups of two to four at a time, with each seated at an individual computer. Each participant group was randomly assigned to one of the four experimental conditions: control (no sound during second task block); ring (cell phone ring recorded from an actual cell phone, assessed by a frequency analysis as 3302 Hz (G#7-10), and digitized to last 2 s with 500 ms of silence at the end of the file); tone (two irrelevant tones, 980 and 490 Hz, played in sequence, digitized to last 500 ms); or song (instrumental version of the fight song converted to digital format, 28.16 s in duration). In the sound conditions, sounds were played throughout the entire second block and were looped to allow them to repeat as many times as necessary. The looping process did not include any breaks in the sound; as soon as the sound file reached the end it immediately began again, thus the sounds were continuous throughout the entire second block of trials. The sounds began at the onset of the first fixation cross in the second block. The sounds were presented through headphones at a level of 72-76 dB(A) as measured by a Quest sound-level meter and earphone coupler. At the end of each experimental session, participants were administered a brief survey to assess their subjective experience with cell phone rings in their daily lives, their awareness of the sounds that had been played during the session and to determine their recognition of the fight song.

## Results and Discussion

All significant findings were based on an alpha level of $p < .05$. Only the RT analyses will be discussed, as the accuracy indices were not sensitive enough to detect any group differences (all *F* values at the block and trial level were less than 1.3 and *p* values were greater than .25); furthermore, there was no evidence of a speed-accuracy trade-off (see Table 1 for the accuracy values). The means of the medians were used for all RT analyses conducted at the block level. Furthermore, only accurate trials were used for all RT analyses, as the RTs for inaccurate trials would be difficult to interpret. In cases where analyses were conducted at the level of the individual trial, the series mean was used to replace missing values from the inaccurate trials. The Bonferroni correction was used for all within-subjects comparisons, and Tukey's post hoc tests were used for between-subjects comparisons.

Due to the a priori predictions regarding the nature of the distraction effects, there was a two-step approach to analyzing the data. The purpose of the first step was to determine if the distraction effects resulting from the various sounds would lead to detriments in performance throughout the entire experimental block. The purpose of the second step was to track the time-course of these distraction effects and to detect potentially subtle differences between the different sound conditions.

The first set of analyses was conducted to determine if group differences would be observed at the block level; thus we collapsed across the trial-type factor to assess potential differences before, during, and after the presentation of the sounds. A 3 (block) × 4 (condition) repeated-measures ANOVA, with block as the within-subjects factor and condition as the between-subjects factor, revealed a block main effect, $F\ (2,308) = 11.72$, $MSE = 24608.90$, $\eta_p^2 = .11$; however, there was no main effect of condition ($p = 0.20$, $\eta_p^2 = 0.03$) and no block by condition interaction ($p = 0.19$, $\eta_p^2 = 0.03$). The block main effect indicated a practice effect, with responses occurring significantly faster as participants advanced across blocks ($M$ = 1215 ms, 1167 ms, and 1130 ms, respectively).

A set of fine-grained analyses were conducted to examine performance at the trial level to assess potential group differences in the time course of distraction effects. Given the above findings of no differences at the block level, these analyses only included the last three trials of Block 1(i.e., the last trials before the sounds began) and the first three trials of Block 2 (i.e., the first trials when the sounds began; see Figure 1). Given that trial type was randomly determined for each individual and was not central to the present investigation, this factor was once again not included in the analyses. First, it was important to establish that baseline performance was the same among all groups of participants. To assess this, RTs for the last three trials of the first block were used as the dependent variable in a mixed-model 3 (trial) × 4 (condition) ANOVA. In this analysis, the within-subjects factor was trial number (18, 19, or 20), and the between-subjects factor was condition (control, cell phone ring, tones, or song). No significant main effects or interactions were observed, indicating that there were no group differences before the ring occurred.

A similar analysis was then conducted on the first three trials on Block 2, to examine the point at which the sounds were introduced in the lexical decision task. This 3 (trial) × 4 (condition) mixed-model ANOVA revealed a significant main effect of trial, $F$ (2, 308) = 27.74, $MSE$ =586900.11, $\eta_p^2$ = .15, a significant main effect of condition, $F$ (3,154) = 14.69, $MSE$ =865757.08, $\eta_p^2$ = .22, and a significant interaction of these factors, $F$ (6,308) = 7.36, $MSE$ = 586900.11, $\eta_p^2$ = .13. To investigate the nature of this interaction, separate univariate ANOVAs were conducted for each of these three trials. Condition differences were observed in trial 1 of Block 2, $F$ (3,157) = 16.11, $MSE$ =1147809.94, $\eta_p^2$ = .24. Post hoc comparisons revealed that responses on the lexical decision task were significantly slower for all three sound conditions (i.e., ring, tone, and song) relative to the control condition, but no differences were observed between the auditory conditions. On trial 2 of Block 2 the effect of auditory condition was again significant, $F$ (3,157) = 3.57, $MSE$ =566603.67, $\eta_p^2$ = .07. While responses in the tone condition were comparable to the control condition, the ring and song conditions still produced significantly slower responses (the latter two groups were not different from one another). By trial 3 of Block 2, RTs were not significantly different among the four conditions; however, there was still a trend for the song group to have slower responses. Interestingly, no systematic differences were observed for the remaining trials in Block 2. The fact that participants could maintain normal levels of performance throughout the majority of the sound trials is consistent with an attentional orienting explanation, suggesting that people can rebound fairly quickly from involuntary orienting responses; however, the differences among the three sound conditions observed in Trial 2 of Block 2, and the difference between the standard ringtone and the familiar university fight song condition observed in Trial 3, suggest that this orienting response was coupled with additional top down processes.

## Survey Data

The survey results indicated that participants in the song condition recognized the university fight song, as nearly all of the participants in this condition (97.5%) labeled it accurately. Other questions pertained to the degree of distraction participants perceived from any sounds they heard during the experiment and whether the sounds may have affected their performance on the task. The ratings from the sound conditions did not differ statistically. Interestingly, nearly all of the respondents (154 out of 155) reported owning a cell phone, and the majority of participants (94.6%) reported hearing a cell phone ring 3 or more times daily. This finding supports the notion that cell phone rings are a pervasive factor in the everyday lives of college students. Finally, only one of the participants in the ring condition and none of the participants in the fight song condition claimed that the sound they heard in the experiment matched their own cell phone ring. This suggests that we cannot attribute the results from this study to perceived similarity of the experimental sounds to that of the participants' own phones; however, we can still assume personal relevance of the fight song given the high rate of recognition.

Overall, the findings from this experiment revealed that lexical-decision performance was negatively affected by a variety of sounds in the environment, with the phone ring and the fight song being more disruptive than the tones. Although the response elicited by the various sounds used in this experiment was consistent with an involuntary attentional orienting response, (i.e., brief response slowing to ongoing activity as a result of novel sounds being introduced), the type of sound affected the time course of the disruption. These findings could reflect the presence of top-down processes in the response to distracting sounds, in that auditory signals which are more frequently encountered and were, therefore, more familiar to these participants led to longer-lasting effects. This issue seems particularly important to consider in light of the survey results which paint a clear picture of the prevalence of cell phones in the life of the undergraduates that were sampled, with 94.6% claiming to hear a cell phone ring 3 or more times every day. Despite the reported prevalence of ringing cell phones, participants were affected by the ring and indicated in their survey responses that ringing phones were moderately to very distracting ($M$ = 6.17).

## Experiment 2

In the second experiment we explored the hypothesis that anticipation of a ringing cell phone could moderate the disruptive effects. The advantage of prior knowledge for minimizing the detrimental effects of auditory distraction would lend support to the premise that top-down processes influence the time course of the response to distracting sounds. The main objective of the second experiment was to investigate whether the anticipation of an auditory distraction would influence the cost experienced. Using a visual search paradigm, Yantis and Jonides (1990) discovered that cueing participant's attention towards a particular spatial location prior to stimulus onset suppressed the attentional orienting response to distracter items that abruptly appeared in the stimulus set. Can cueing people about the potential for distracting sounds also reduce the attentional costs observed as a result of the sound being introduced into the environment?

To answer this question, we first randomly divided the participants into three groups; one group was the control and the other two experienced the ringing distraction. We manipulated anticipation of distraction by warning half of the participants in the ring condition that a distraction would occur at some point. We predicted that all participants who were exposed to the ring would produce slower and less accurate responses compared to those in the control condition, regardless if they had been warned about the potential for auditory distraction. We further predicted that if attentional orienting processes were supplemented by additional top-down processes (see Roye et al., 2007), warned participants should resume normal task performance more quickly than the non-warned participants once the involuntary response to the novel sound has occurred.

## Method

### Participants

Seventy-three undergraduates from Louisiana State University with no self-reported hearing loss and English as their first language were randomly assigned to one of three conditions; there were 21 in the control condition (16 female), 25 in the non-warned condition (20 female), and 27 in the warned condition (23 female). Participants received course credit or extra credit in psychology courses for their participation.

### Materials/Procedure

The same task and procedure was used as in Experiment 1; the only change was the use of a different experimental manipulation. In this study, two experimental conditions were tested to determine if anticipation of an auditory distraction could attenuate the cognitive costs resulting from a cell phone ring. In the control condition, participants completed the lexical decision task without the presence of a ringing phone. In both experimental conditions the phone ring was played during the entire second block. The cell phone ring used in this experiment was the same as in Experiment 1. Participants in the treatment condition were randomly divided into two subgroups: warned and non-warned. The warned group was told in the written instructions that a distracting sound would occur at some point in the task, and the non-warned group completed the task without any warning of an auditory distraction.

## Results and Discussion

As in Experiment 1, means of the medians were used to examine the RT data at the block level. The two dependent variables were accuracy and RT; as before, only RT measures will be discussed, as they provided a more sensitive measure of performance (see Table 1 for accuracy results). The first analysis was a 3 (block) × 3 (condition) mixed-model ANOVA with block as the within-subjects factor and condition as the between-subjects factor to assess global trends in performance before, during, and after the presentation of the sounds. Neither the main effect of group ($p = 0.97$, $\eta_p^2 = 0.00$) nor the interaction with condition ($p = 0.54$, $\eta_p^2 = 0.02$) was significant. The main effect of block, $F$ (2, 140) = 13.87, $MSE$ = 84046.60, $\eta_p^2 = 0.17$ was significant. Again like Experiment 1, the post-hoc comparisons indicated that the block main effect can be explained as a practice effect; Block 1 was significantly slower than Blocks 2 and 3, with no other significant differences ($M$ = 1263 ms, 1179 ms, and 1139 ms, respectively).

The next set of analyses were conducted to take a closer look at the time course of distraction caused by the onset of the ring and how warnings prior to the ring might influence these disruptive effects. As in Experiment 1, analyses were conducted at the trial level with a 3 (trial) × 3 (condition) mixed-model ANOVA. The within-subjects variable was the trial number (18, 19, or 20) and the between-subjects variable was the condition (control, warned, or nonwarned). No significant findings emerged from this analysis, indicating no performance difference among condition prior to experimental stimulus.

A similar analysis was conducted using the first three trials of Block 2 (i.e., when the sounds began for those not in the control group). This 3 (trial) × 3 (condition) mixed-model ANOVA revealed a main effect of trial, $F$ (2, 164) = 9.57, $MSE$ = 338395.98, $\eta_p^2 = 0.11$, a main effect of condition, $F$ (2, 82) = 9.70, $MSE$ = 902874.08, $\eta_p^2 = 0.19$, and a significant trial by condition interaction, $F$ (4, 164) = 5.43, $MSE$ = 338395.98, $\eta_p^2 = 0.12$. To understand the nature of this significant interaction, a series of univariate ANOVAs were conducted for the first three trials of Block 2. This analysis revealed a significant difference among the three conditions, $F$ (2, 70) = 10.29, $MSE$ = 967993.63, $\eta_p^2 = 0.23$, and post-hoc comparisons confirmed that the control condition was significantly faster than both the warned and non-warned conditions, which did not differ. We then examined the second trial of Block 2, and again found a significant effect, $F$ (2, 70) = 8.12, $MSE$ = 403414.38, $\eta_p^2 = 0.19$. The pattern of differences indicated that the non-warned condition was significantly slower than the two other conditions, which did not differ. Finally, no condition differences were observed in the third trial of Block 2 (see Figure 2).

These findings suggest that being warned about the potential for an auditory distraction helped to facilitate an even quicker recovery from the onset of the ring. This is consistent with research on visual attention that has demonstrated protection from distracting information as a result of providing spatial cues prior to target onset (Yantis & Jonides, 1990). These findings support the hypothesis that although orienting responses to a cell phone ring lead to brief distractions from ongoing task activity, prior knowledge about the potential for extraneous auditory signals diminishes the negative effects of the ring. This suggests a role for top-down processes to attenuate the effects of involuntary attentional orienting.

A potential limitation of the first two experiments pertains to the artificial nature of the experimental setting and the use of a laboratory task that is not typically seen in real-world settings. Cognitive activities that demand sustained attention, such as listening to a lecturer, are a common feature present in the daily lives of most adults; however, these activities are presumably quite different from making lexical judgments about letter strings presented on the computer screen. A classroom setting in which students must sustain attention to a lecturer while also retaining information in memory provides a more realistic environment for testing the distraction of a ringing cell phone. Furthermore, hearing a phone ring in an experimental laboratory may be accurately perceived as a form of manipulation rather than an actual cell phone ring. Thus, Experiments 3a and 3b attempted to remedy these potential limitations.

## Experiment 3a

The findings from Experiments 1 and 2 demonstrated that introducing a phone ring into an experimental setting significantly disrupted performance on laboratory-based cognitive tasks, particularly when people did not anticipate a distracting sound wouldl occur. The survey results from Experiment 1 further suggested that participants were frequently exposed to ringing cell phones in their daily lives and felt that this exposure led to distraction from their ongoing activities. An important question that remains unanswered is whether or not the presence of cell phone rings in real-world settings negatively impacts people's performance on their daily activities. The purpose of Experiments 3a and 3b was to explore this question by examining how a cell phone ring affected students' performance in a college classroom setting.

Although all four experiments investigated the effects of a ringing phone on participants' cognitive performance, Experiments 3a and 3b used a different task to measure cognitive performance as compared to the lexical decision task in Experiments 1 and 2. Instead of simply recognizing word and non-word pairs, participants in the field experiments were students in a college course who were tested on their memory for facts presented during a lecture. The assessment of concepts learned during portions of the lecture that were and were not accompanied by the presence of a ringing phone, via a multiple choice quiz, created a more realistic measure of cognitive deficits caused by this commonly encountered auditory distraction. This change in the dependent measure allowed an investigation of whether or not the involuntary attentional orienting response found in the laboratory tasks would transfer to a real-world setting encountered in the daily lives of students.

## Method

### Participants

Participants were 33 undergraduate LSU students (27 females) enrolled in a sophomore-level child psychology course during an intersession (a 2 week semester with classes lasting 3 hours per day).

### Materials/Procedure

Participants attended the first day of the semester and were not given any warning that an experiment would be occurring during the lecture. After a 15-minute break 2 hours into the class, the lecturer began to discuss prenatal development. During this lecture, students had outlines of the notes in which they were filling in blanks and writing in descriptions from the PowerPoint slideshow created by the instructor. Near the end of the lecture, the instructor began discussing when the various senses become operational for the fetus. The first sensory system discussed was touch, followed by a discussion of taste and smell. Next, the instructor presented material about the development of hearing in the fetus and ended with the material related to sight development. At the beginning of the section on hearing development, students were given the opportunity to write down all of the material presented on the slide. Once students had written down this information, the lecturer announced that “the sense of hearing develops at about 25 weeks.” This statement prompted a confederate seated near the middle of the classroom to activate a cell phone (using another cell phone hidden in her pocket) located at the bottom of her book bag.

The ring was a standard ringtone (ringtone offered on a Verizon LG mobile phone), and the volume of the ring was measured at a level of 66-68 dB(A) by a Quest sound-level meter. This level was assessed by holding the sound-level meter outside of the bag at a distance of approximately 3 feet, with the phone ringing inside of the bag. The confederate allowed the phone to ring for approximately 30 seconds while appearing to search for the phone. The instructor continued presenting the material while the cell phone was ringing, talking over the sound of the ringing phone. Her voice was clearly audible over the sound of the phone, as perceived by the confederate (who was seated closest to the phone, which was in her bag). After the cell phone was silenced, the instructor completed the ongoing material pertaining to hearing and proceeded to the section about sight. Finally, the students viewed a short 3-minute video clip about the embryonic stage of development.

Approximately 5 minutes after the critical information was discussed, students were told that they had the opportunity to earn extra credit by completing a pop quiz over the material covered in class that day. The quiz consisted of 6 multiple-choice questions (with 4 answer options) and 2 short-answer questions; however, only the critical multiple-choice questions will be reported to allow comparisons across Experiments 3a and 3b. One of the multiple-choice questions was directly from the hearing section of the lecture and concerned a date (i.e., 25 weeks) which was posted in the visual presentation and should have been written down in the students' notes prior to the cell phone ring and instructor's verbal presentation of this information. A multiple-choice question pertaining to taste development served as a related control question. It was identical in format to the hearing question, but instead of the word “hearing” it contained the word “taste.” The multiple choice options for both questions were identical as well. Additional questions were created from other parts of the lecture on prenatal development to decrease the likelihood of participants guessing the reason they were taking the quiz. Once the quizzes were collected, the lecturer told the participants that they had just taken part in a study. Before the experiment was fully explained to the students, they were asked to complete consent forms, authorizing the use of their data. Finally, the students completed a version of the survey used in Experiment 1 that was modified slightly for the present purposes. After completing the survey, participants were fully debriefed about the nature of the study and the reasons for using deception.

## Results and Discussion

A few terms regarding the question types should be clarified before presenting the quiz data. The term “experimental” will be used to reference the quiz question related to the portion of the class when the cell phone was ringing. The term “control” pertains to the quiz question that was matched to the experimental question in terms of type of material and difficulty level. Descriptive information was examined for the students' accuracy using proportion correct for each question type, as well as overall quiz scores.

Student's overall performance on the quiz was fairly low (see Table 2); however, this was mostly driven by their poor performance on the experimental question, as they were fairly accurate in answering the control and other filler questions. The experimental and control questions were compared in a paired-samples $t$ test, $t(32) = 3.714$, $p < 0.01$, confirming the observation that performance on the experimental question was significantly lower than performance on the control question.

This finding suggests that the presence of a ringing cell phone in the classroom led to significant disruption in students' memory for information presented while the cell phone was ringing. This deficit was observed in scores from the experimental/control comparison even though the information pertaining to the experimental question was presented visually, allowing students the opportunity to record it in their notes prior to the onset of the ring and the verbal presentation of the material from the instructor. This retroactive memory loss for information presented prior to a distracting sound is consistent with findings from the irrelevant sound literature (Norris, Baddeley, & Page, 2004).

Next, we will discuss the outcome of the survey data to assess subjective appraisal of the impact of the cell phone ring, as well as their opinions on cell phone activity in general. Twenty-nine of the 33 students who completed the survey identified the cell phone ring as the sound that was heard during class. The remaining 4 students referenced other sounds from the classroom and were not considered in the remaining survey data. Student's ratings on a 1 to 10 Likert scale (with 10 labeled as very distracting) suggested that they considered the ring to be highly distracting ($M = 7.72$, $SD = 2.53$) and believed that it led to moderate levels of disruption ($M = 6.62$, $SD = 2.53$) from their ongoing classroom activity (e.g., taking notes, listening to the instructor). All of the students reported owning a cell phone and hearing cell phones ring in their daily lives quite frequently (79% said 5 or more times daily; 21% said 3 to 4 times daily). Students felt that hearing cell phones ring in the environment was moderately distracting ($M = 6.48$, $SD = 2.54$). The outcome of these survey data are consistent with those from Experiment 1 and suggest that cell phone rings are pervasive in the daily lives of college students and tend to distract them from their ongoing activities.

## Experiment 3b

The results of Experiment 3a suggested that cell phone rings were disruptive in the classroom setting; however, the results may have been confounded by the presence of a visual distraction. The confederate searched through her bag while the phone was ringing, appearing to try to silence the ring. This may have created a visual distraction effect in addition to any distraction present from the ringing phone. To address this issue Experiment 3b was conducted. Two major changes are noteworthy. The first is that the confederate allowed the phone to ring without searching for it or moving at all, and the second is that the position of each individual in the classroom was recorded in reference to the position of the confederate and her ringing phone.

## Method

### Participants

Participants were 27 LSU undergraduate students (20 females) enrolled in a sophomore-level honors introduction to psychology course during the regular spring semester. The class met for 1.5 hours two times per week. None of these students took part in any of the previous experiments.

### Materials/Procedure

As in Experiment 3a, the participants were not given any warning that an experiment would occur during the lecture. The experiment was conducted on the third day of the course, during the period in which students were adding and dropping the course, so that the confederate was not noticed as an unusual member of the class. The same confederate from Experiment 3a participated in the experiment and used the same cell phone, set to the same ring and volume setting as before. Additionally, she used the same bag and placed her phone in the same location within the bag as in Experiment 3a. Furthermore, the same instructor from Experiment 3a delivered the same lecture on child development (she served as the teaching assistant for this course, taught by the second author). However, for this experiment, the timing of the onset of the cell phone ring was modified so that the material that had previously been considered the "experimental" and "control" material could be exchanged. This allowed for an assessment of the difficulty level of the questions across the two samples. Thus, the multiple-choice question pertaining to hearing became the control question and the question pertaining to taste became the experimental question. Similar filler questions were used as in Experiment 3a to keep the students from detecting the purpose of the quiz. The format of Experiment 3a was followed as closely as possible in every other detail.

## Results and Discussion

The findings from this experiment generally replicated Experiment 3a (see Table 2). Performance on the control and experimental multiple-choice questions was evaluated with a paired-samples $t$ test, $t$ (26) = -2.054, $p = 0.05$. This analysis demonstrated that the difference in performance on these questions was marginally significant. Thus, the confederate's ringing phone disrupted performance, but not to the same extent as in Experiment 3a. This finding suggests that cell phone rings as isolated events are distracting, but that additional behavior that often accompanies cell phone rings, such as reaching into a book bag to search for the ringing phone, may also be an important component of the distraction that results.

Additionally, the position of the participants in relation to the confederate's location in the classroom was recorded by the second author, who appeared to be taking lecture notes. The classroom contained tables instead of individual desks, and students seated at tables close to the confederate's table (n = 11) were compared to those sitting at tables farther away from the confederate (n = 16), on the basis of a horizontally-oriented grid which was created to represent the classroom space. Performance on the experimental multiple-choice question was analyzed as function of position using an independent samples $t$ test, $t$ (25) = 0.84, $p =$ 0.93. The results of this analysis provide clear evidence that the location of the ringing phone within the classroom did not influence performance. These results further supported the subjective evidence from Experiment 3a that the ringing phone did not mask the instructor's voice.

Finally, the survey results from this experiment were very similar to Experiment 3a. Of the 27 participants, 25 clearly identified a ringing cell phone as the sound heard in the classroom. All of the students reported owning a cell phone.

## General Discussion

The results of the present research revealed new evidence about the distracting effects of cell phone rings. Although the ringing sound was detrimental to cognitive performance in both the laboratory and real-world settings, the effects were very short lived in the laboratory setting. The brief effects observed in the laboratory (Experiments 1 and 2) were consistent with an attentional orienting explanation (Cowan, 1995), coupled with additional top-down processes. These experiments demonstrated that participants were affected by either the type of distracting sound or the prior information given about the potential for auditory distraction. This supports previous research suggesting the type of sound presented and the presence of warnings influence the amount of cognitive costs observed in response to novel sounds introduced into the environment (Berti & Schröger, 2003).

The four experiments reported here were consistent with prior research demonstrating negative effects of irrelevant sounds in the performance of both real-world and laboratory-based cognitive tasks (Banbury & Berry, 1998; Beaman, 2005; Escera et al., 1998). To summarize the main findings, in Experiment 1, participants were asked to complete a lexical decision task, and were divided into groups who either heard no sound, two tones, a standard phone ring, or their university fight song. Patterns of RTs revealed that performance was disrupted by the presence of these sounds, but that participants were able to quickly return to baseline levels of performance. However, those hearing the phone ring and the fight song needed one more trial to return to baseline. This research further suggests that the high prevalence of cell phones and the propensity with which they ring (as supported by the survey data) are not necessarily detrimental to cognitive performance on laboratory-based tasks over the long term.

In Experiment 2 the same lexical decision task and cell phone ring were used, and participants were either warned in advance that a distraction may occur, or were not warned about the potential for distraction. These two groups were compared to a control condition in which no ringing sound occurred. The findings demonstrated that the warning helped participants to recover even more quickly. These findings point to the importance of top-down processes in recovery from distracting information.

The purpose of Experiments 3a and 3b was to determine if the distracting effects of a cell phone ring would extend to an applied setting. Students enrolled in undergraduate psychology courses were exposed to the ringing cell phone of a confederate seated in the classroom and were later tested on their memory for information presented during the ring, relative to other information presented in the lecture. The results revealed extremely low accuracy levels on questions pertaining to the portion of the lecture when the ring occurred. This strong effect was observed for information that was presented visually and verbally by the instructor. Furthermore, the distracting effects of the cell phone ring were observed both when the confederate searched through her bag to silence the phone (Experiment 3a) and when she simply let the phone ring (Experiment 3b). The additional visual distraction of the bag search did, however, elicit a larger distraction effect. This outcome is consistent with the premise that the disruptive nature of noise in the environment has important practical implications (Banbury et al., 2001; Beaman, 2005). In addition, other cell phone research has revealed large distraction effects in real-world settings. For example, talking on a cell phone while operating a high-fidelity driving simulator has been shown to result in serious consequences, such as slowed braking responses, running through red lights, and increased likelihood of having a collision (Strayer et al., 2003). These effects were attributed to the cell phone conversation absorbing important voluntary attentional resources needed to respond efficiently to incoming information in the driving field.

The observed outcomes of the first two experiments were consistent with an involuntary attentional orienting explanation in that disruptions to ongoing task performance were brief with a rapid recovery to baseline performance despite the continued ringing noise. There are, however, alternative explanations that point to the presence of voluntary attentional processes. Task-switching studies have consistently demonstrated that people will be slower and more error-prone in their ongoing task activity at the point in which they have to shift between different task sets (for review see Monsell, 2003). Monsell (2003) argued that,

> the cognitive task we perform at each moment, and the efficacy with which we perform it, results from a complex interplay of deliberate intentions that are governed by goals (‘endogenous’ control) and the availability, frequency, and recency of the alternative tasks afforded by the stimulus and its contexts (‘exogenous’ influences). (p. 134)

This account is particularly relevant to the findings from the final two experiments[1]. For example, when the students made the decision to attend class on the days in which the experiments took place, their task sets associated with classroom behavior were likely activated (i.e., paying attention to the instructor, taking notes, etc.). During class, a potentially more socially interesting situation arose (a student's phone ringing), causing the students to shift their attention away from the previously held goal of obtaining the class-relevant material. The ringing phone alone may not have caused students to engage in a new task, but this coupled with other factors, such as watching a fellow student search through their bag for a ringing phone or noticing that another student was allowing their phone to ring during class served as a sufficient distraction. Thus, the endogenous goal of paying attention to the lecture interacted with the exogenous influence of the cell phone situation. Future research is needed to better isolate the factors associated with the cognitive response to a ringing phone, but it is possible that the complexity of real-world environments leads to a different response by the cognitive system (resulting from an interaction between multiple cognitive and social factors) than that observed in more controlled laboratory settings.

Taken together, these four experiments clearly demonstrated that cell phone rings disrupted cognitive performance, and certain factors affected the level of disruption experienced. Several practical implications emerge from these findings. For example, being in a situation in which one anticipates a ringing phone would cause distraction from an ongoing task, but a quick recovery from this distraction could be expected. However, when a cell phone ring is unexpected, in an environment such as a classroom, the disruptive effects may be sustained for longer. In addition, the findings from the fight song condition indicate that familiar songs commonly used as cell phone rings have the potential to cause more sustained disruptions. This particular finding points to a potential future direction in this line of research. Is it more distracting to hear one's own personalized cell phone ring, as opposed to a bystanders' ring? Electrophysiological research suggests that the brain response to a personal ringtone differs from the response to another ringtone that does not contain personal significance (Roye et al., 2007). Additional research addressing this question could provide important information about the factors that contribute to distraction caused by cell phone rings in real-world environments. For example, if hearing one's own cell phone ring during class disrupts the learning experience more than hearing a classmates' phone ring, this could reflect the importance of certain social factors in these distraction effects. Furthermore, the expectation of getting a phone call during the day may impact a person's ongoing activity, and this expectation may or may not have the same protective effects as those observed in the laboratory. Future research should address performance on a broader array of tasks, and in

[1]We would like to thank C. Philip Beaman for pointing out this alternative.

other applied settings, to determine if the magnitude and time course of disruption experienced varies with task difficulty and environmental setting.

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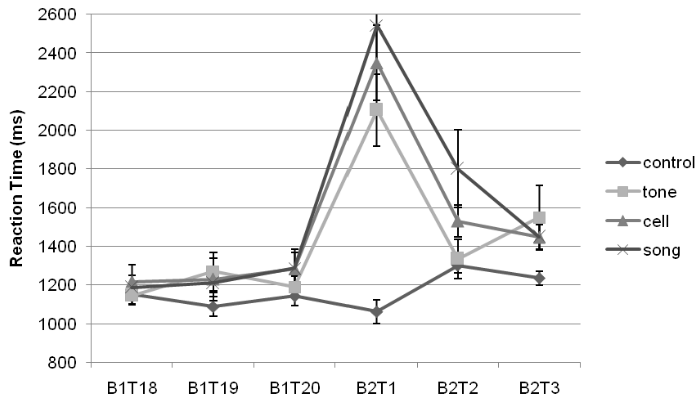


**Figure 1.**

Means of reaction times for the lexical decision task in Experiment 1 for the four groups of participants on the trials before and during the auditory distracters (i.e., the last three trials of Block 1 and the first three trials of Block 2). B1T18 refers to Block 1 Trial 18 and so forth, while B2T1 refers to Block 2 Trial 1 and so on. Error bars represent standard error of the mean.

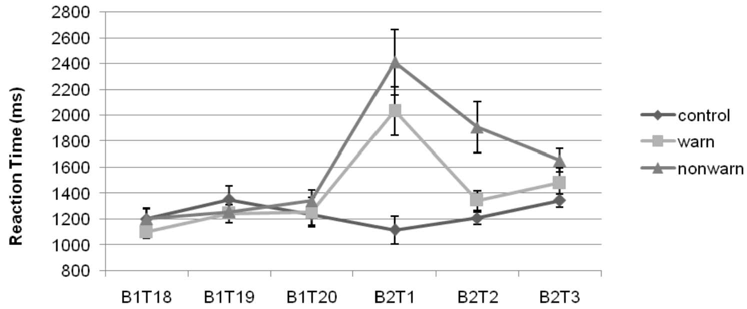


**Figure 2.**

Means of reaction times for the lexical decision task in Experiment 2 for the three groups of participants on the trials before and during the cell phone ring. B1T18 refers to Block 1 Trial 18 and so forth, while B2T1 refers to Block 2 Trial 1 and so on. Error bars represent standard error of the mean.

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**Table 1**

**Accuracy Values for Experiments 1 and 2 with Standard Deviations in Parentheses**

| Expt. 1 | B1T18 | B1T19 | B1T20 | B2T1 | B2T2 | B2T3 |
|---|---|---|---|---|---|---|
| Control | 0.86 (0.35) | 0.84 (0.37) | 0.77 (0.42) | 0.91 (0.29) | 0.75 (0.44) | 0.73 (0.45) |
| Tone | 0.75 (0.44) | 0.89 (0.32) | 0.86 (0.35) | 0.81 (0.40) | 0.75 (0.44) | 0.69 (0.47) |
| Cell | 0.87 (0.34) | 0.92 (0.27) | 0.92 (0.27) | 0.82 (0.39) | 0.71 (0.46) | 0.76 (0.43) |
| Song | 0.85 (0.36) | 0.83 (0.38) | 0.83 (0.38) | 0.93 (0.27) | 0.85 (0.36) | 0.65 (0.48) |
| Expt. 2 | B1T18 | B1T19 | B1T20 | B2T1 | B2T2 | B2T3 |
| Control | 0.90 (0.30) | 0.81 (0.40) | 0.90 (0.30) | 0.95 (0.22) | 0.76 (0.44) | 0.76 (0.44) |
| Warn | 0.78 (0.42) | 0.85 (0.36) | 0.93 (0.27) | 0.96 (0.19) | 0.74 (0.45) | 0.78 (0.42) |
| Nonwarn | 0.88 (0.33) | 0.84 (0.37) | 0.96 (0.20) | 1.00 (0.00) | 0.92 (0.28) | 0.76 (0.44) |

**Table 2**
**Mean Percentages of Performance on the Quiz Questions in Experiments 3a and 3b**

| Question | Experiment 3a | Experiment 3b |
|---|---|---|
| Overall Average | 64 | 71 |
| Taste Multiple-Choice Question | 70 (Control) | 44 (Experimental) |
| Hearing Multiple-Choice Question | 30 (Experimental) | 70 (Control) |