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A ringing phone

The distracting effect of ringtones

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2017

Student thesis, Advanced level (Master degree, one year), 15 HE
Environmental Psychology
Master Programme in Environmental Psychology

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Preface

Special thanks are directed to my supervisor John Marsh for his constructive critique and helpful advice with this thesis, my teacher Robert Ljung for preparing me for the task. I also want to thank my classmate Tomas Hansson and the researchers at The Institution for Environmental Psychology at University of Gävle in assisting me with the experiment. I'm grateful for the participation of the students at Gävle University.

Abstract

Ringing phones are common in work space environments in the 21th century and while capturing the attention of the call-taker they also tend to disrupt people in the surrounding environment. This study aims to investigate the attentional capturing effect of ringtones by comparing sudden and increasing onsets with quiet and noise masking conditions while participants undertook a test of short-term memory for serial order (serial recall). The experiment presented new evidence that increasing ringtone sounds have a disruptive effect on serial recall processing. A masking noise background, however, successfully eliminated the effect of the increasing ringtone sound. In contrary to what was anticipated, the ringtone with the sudden onset did not cause an attentional capture effect, suggesting at least in behavioural terms, it was successfully ignored. The results are discussed in relation to the literature on looking effects. Increasing ringtone sounds may appear looming, with sudden onset sounds decreasing in volume appearing receding. The central idea is that looming sounds are more disruptive to serial recall because they cause a diversion of attention from the serial recall task so as to react to the apparently approaching sound. The disruption attributable to looming sounds may be a form of attentional capture that is more specific than those triggered by deviant events within a to-be-ignored stream of sounds.

Keywords: Ringtones, Attentional capture, Looming effect, Irrelevant sound, Masking noise, Serial recall.

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1 Introduction

You're reading a text in the library when someone's phone suddenly starts ringing with a melody that's echoing through the open space of the building. As the phone continues to ring you try to focus your attention on the text, but you stop because you get lost. Does this scenario seem familiar to you? Why does sound have the ability to disrupt our selective attention to a task?

Our sense of hearing has the capacity to receive information at any time and is especially responsive to change (Banbury, Macken, Tremblay & Jones, 2001; Hughes & Jones, 2003). The evolutionary reason for this capacity of the hearing sense is to detect changes in energy in our surroundings that could warn against immediate danger (Banbury et al., 2001). Although advantageous for detecting threat, the problem with this ability to nonconsciously hear changes in sound can be a disadvantage: When our sense of hearing registers irrelevant sounds in our environment it can sometimes cause our concentration on tasks, especially complex ones, to diminish, or break (Banbury et al., 2001). This is called auditory distraction. While this ability to nonconsciously process sounds can disrupt attention, it is also a crucial ability for humans to detect and act upon critical changes in their environment (Hughes & Jones, 2003).

From the perspective of the attentional capture approach (e.g., Cowan, 1995; Hughes et al., 2013) a ringtone with a sharper, as opposed to softer, onset should be able of capturing attention away from an ongoing focal task, thereby causing the individual to pay attention to the ringtone (Hughes, Hurlstone, Marsh, Vachon & Jones, 2013). This is because the magnitude of attentional capture is typically a function of the difference between what is perceived and expected (Nöstl, Marsh, & Sörqvist, 2014): A sharp onset of sound is arguably less similar to quiet than a soft onset of sound and should therefore produce greater disruption. Alternatively, from the point of view of the literature on looming, a ringtone with a soft onset that increases in volume should produce greater distraction than one decreasing in volume from a sharp onset. This is since a ringtone increasing in volume should simulate the sound of an approaching/looming object. Looming sounds pose the greatest risk since looking signifies time to impact. Indeed such sounds trigger a panoply of physiological, cognitive, emotional, and behavioral responses that serve to protect the organism (Neuhoff, 2016).

This study aims to compare the potentially attentional capturing effect of increasing and decreasing ringtone sounds with each other to better understand which ringtone design is least distracting to serial recall performance when presented as irrelevant sound. The ringtones are also compared to a quiet and masking noise background in order to establish whether masking noise can diminish the potency of the irrelevant sounds to capture attention.

2 Theory

Psychologists typically study auditory distraction with the irrelevant sound effect paradigm. In this paradigm, participants are visually presented with a list of 6-9 verbal items (typically letters or digits) that they are required to recall in strict serial order. The primary means by which individuals retain visually-presented sequences of items across the short-term is via serial rehearsal, using inner speech. The presence of sound that is not relevant to the task and that participants are told to deliberately ignore, depresses serial recall performance considerably, as compared with quiet (Colle & Welsh, 1976; for a review, see Banbury et al., 2001).

There are different theories concerning the how the irrelevant sound effect becomes manifest. One dichotomy between these theories relates to the importance of, on the one hand, similarity of content between to-be-remembered and irrelevant items (similarity of content theories; e.g., Salamé & Baddeley, 1982) and on the other hand, similarity of process between the automatic processing of the serial order of changes within the sound, and the deliberate process of using speech-based motor processing to serially rehearse the visual items (similarity of process; Jones & Tremblay, 2000).

Perhaps the most well-known similarity of content theory is based on the Working Memory model (Baddeley, 1986). This approach supposes that the disruption irrelevant sound produces takes place within a component of the Working Memory system called the phonological loop. The phonological loop is responsible for the short-term maintenance of acoustic, verbal and phonological information (Baddeley, Eysenck & Anderson, 2009) and comprises two subcomponents. These are the phonological store, which has a decay time of one to two seconds, and the articulatory control process. The articulatory control process is a rehearsal mechanism that uses an "offline" speech planning process (essentially inner speech). Subvocal rehearsal of the decaying traces of to-be-remembered items within the phonological store revivifies their traces and allows the short-term maintenance of visually-derived information. Unlike visual items that obtain access to the phonological store through a grapheme-phone conversion process undertaken by the articulatory control process, task-irrelevant sounds gain direct entry into the phonological store. Herein they mask or otherwise interfere with the representations of to-be-remembered items from the visual source to the rate that they are phonologically similar to those items (Salamé & Baddeley, 1982). The Working Memory model account of the irrelevant sound effect correctly explains why it is independent of sound pressure level: Sounds at the level of a whisper (48 db(A)) produce equivalent disruption to sounds at the level of a shout (76 db(A)).

However, this interference by content account is undermined by several findings. First, in contrast to an initial study (Salamé & Baddeley, 1982), the similarity in phonological content between to-be-remembered items and irrelevant auditory items does not increase the degree of disruption (Jones & Macken, 1995). Moreover, non-speech sounds with no phonological content (and therefore unable to be represented in the phonological store) produce marked distraction provided they exhibit appreciable acoustic change between their segmentable entities (Jones & Macken, 1995). This fueled the development of an alternative approach called the interference-by-process account (Jones & Tremblay, 2000).

The interference-by-process account (Jones & Tremblay, 2000) is built on the observation that strong and robust irrelevant sound effects occur only when there is appreciable acoustic change between successive items (in terms of pitch or timbre) within the auditory sequence and when efficient task performance requires serial rehearsal (Jones & Macken, 1993). Part of the interference-by-process account is based on the changing-state effect. This refers to the finding that a sequence of different letters or tones varying in pitch produce far more disruption that a single letter or tone repeated over (Jones & Macken, 1993). The changing-state effect only emerges for tasks that require serial order. If the task involves presenting participants with 8 items from a well-known set of 9 items and requesting them to identify which item was not presented (the missing-item task), no changing-state effect occurs. Therefore, the occurrence of the changing-state effect is a joint product of the properties of the irrelevant sound and the type of process involved in the focal task (Banbury et al., 2001; Hughes, Vachon & Jones, 2007; Jones & Macken, 1993; Jones, Madden & Miles, 1992; Macken & Jones, 2003).The interference-by-process account makes two key predictions. One is that if the reliance on serial rehearsal in the short-term memory task is reduced, the magnitude of the irrelevant sound effect will be also reduced. The second prediction is that if the amount of auditory changes, and therefore cues for seriation, in the irrelevant stream is reduced, the magnitude of the irrelevant sound effect will also be reduced. Consistent with this latter prediction, the degree of disruption by phonological sounds is reduced when each sound is assigned to a separate auditory stream on the basis of frequency or spatial separation, while the phonological content remains the same (Macken & Jones, 2003).

Neither the interference-by-content account (Salamé & Baddeley, 1982), nor the interference-by-process account (Jones & Tremblay, 2000) suggest that attention is involved in the irrelevant sound effect. This contrasts sharply with the attentional capture approach of Cowan (Wood & Cowan, 1995; Cowan, 1998). On the attentional capture approach (e.g., Cowan, 1995), each change within a changing sequence triggers an orienting response whereby attention is captured away from the focal task by the sound event. However, this approach assumes that the presence of a deviant in a changing-state sequence of sounds will have less impact than one presented in a sequence of repeated sounds, since each changing sound will already be capturing attention. At odds with this prediction, Hughes, Vachon and Jones (2007) found that both were equally disruptive of serial recall. This observation led Hughes et al. (2007) to suggest the duplex mechanism account. Here, sound can either cause unwanted distraction by interfering with the processes involved in the task (inference-by-process, the changing state effect) or by shifting the attention away from the focal task noncontingently of the processing the task requires (attentional capture, the deviation effect).

Within the duplex account, the attentional capture mechanism assumes that an unexpected sound that deviates from otherwise predictable sounds (e.g., the b in the sequence “aaaaaaabaaa”) causes a shift of attention away from the focal task, independent of the type of processing that the task involves (Hughes, Vachon, & Jones, 2007). Attentional capture by deviant sounds has been demonstrated by using the deviant (or oddball) paradigm in which an unusual, surprising sound deviates from the auditory context in which it is embedded (Hughes, Hurlstone, Marsh, Vachon & Jones, 2013). The attentional capture mechanism, unlike the case with interference-by-process, is noncontingent on the type of focal task executed. For example, Vachon, Labonté, and Marsh (2016) conducted two experiments to determine whether the deviation effect reflects a stimulus-driven or a task-contingent orienting mechanism. Vachon et al. (2016) found that both verbal and spatial deviants can affect both verbal and spatial order-reconstruction for the correct position of sequentially presented dot locations and missing-item tasks wherein one has to identify the location of a dot that was not presented from a number of well-known locations or a verbal item that was not presented from a well-known set of items.

Arguably the potential disruption that arises from a looming sound object (the looming effect) is a form of attentional capture that is more specific than that of typical voice or item deviants. The looming effect is observed with sounds with onsets that thereafter increase in strength as opposed to sounds with onsets that thereafter diminish in strength (Neuhoff, 2016). In a series of experiments, Neuhoff (2016) found that participants were biased to perceive looming sounds to move faster than receding sounds. In neurological studies by Ingham, Hart and McAlpine (2001) and Wilson and O'Neill (1998) looming sounds produced a greater response in single-neurons in the inferior colliculus (IC) than receding sounds in experimental animals (guinea pigs and Jamaican Parnell's mustached bats) indicating that the looming effect can be a mammal trait of the sense of hearing. Neuhoff (2016) explained the looming effect by proposing that it is an evolutionary advantage for humans to react early to sounds of looming objects with the purpose of evading danger. The looming effect has shown that humans tend to overestimate the speed and distance to looming sounds. Neuhoff (2016) explains that this tendency to overestimate in reaction to looming sounds is associated with an evolutionary advantage so as to prepare the organism for possible looming dangers in its environment. Recent studies (McGuire, Gilliath & Vitevitch, 2016) exposed listeners to a high cognitive load (memorizing a seven digit number) or low cognitive load (memorizing) a two digit number while judging the arrival of looming sounds. The participants reacted sooner to the looming sounds while under a high cognitive load than under a low cognitive load which could implicate that the looming sounds had a greater distractive effect when subjected to a high cognitive load. Since the serial recall task is one that requires a high load (as indexed by increased rehearsal of to-be-recalled items) one might expect the task to be susceptible to distraction via looming sounds.

By simulating an irrelevant sound capable of diverting the listener's attention, sound alarms, or auditory warnings, should be capable of capturing attention and providing information to an operator about an urgent task that needs to be attended to (Edworthy & Hellier, 2000; Ljungberg & Parmentier, 2012; Wolfman, Miller & Volanth, 1996). By using buzzers, bells, horns or beeps systems the alarm attempts to drag a listener's attention away from the task in which they are currently engaged, to the alarm (Wolfman et al., 1996). It's also common that older non-speech auditory warning systems get replaced by speech warning systems (Edworthy & Hellier, 2003). The advantage of auditory warnings compared to visual warnings is the ability of being processed by the cognitive system even if the users is focusing their attention on something else (Ljungberg & Permentier, 2012; Wolfman, Miller & Volanth, 1996).

Non-speech alarms can consist of a short pulse of sound with several harmonics that repeats several times at different pitches, with time intervals between them (Edworthy & Meredith, 1994). This combination of pulses creates an atonal melody with a rhythm. A typical example would be the sound of the sirens on police cars. The alarms' ability to capture attention is termed urgency. Usually the urgency of non-speech alarms is altered by changing pitch and volume, speed and frequency of pulses in every burst while urgency in speech alarms are measured by tone of the speech and the message conveyed (Edworthy & Hellier, 2003; Hellier, Edworthy, Weedon, Walters & Adams, 2002). Peoples' ability to subjectively rate the urgency of alarms do not necessary match the alarms urgency when measured with behavioral performance (Ljungberg and Permentier, 2012).

The auditory warnings in cell phones and smartphones have a good probability of disrupting people even when they're supposed to only inform a single user of an incoming call, new message or news on an application (Röer, Bell & Buchner, 2014). It would not be a big problem if it weren't for the 21th century's technological advancements. Suddenly many of the residents in western societies have smartphones with their own alarms buzzing, ringing, beeping and playing melodies to captures its user's attention at school, work and other places where the ringtone is irrelevant and distracting to anybody but the call taker (Röer et al., 2014; Shelton, Elliot, Eaves & Exner, 2009; Stothart, Mitchum & Yehnert, 2015; Thornton, Faires, Robbins & Rollins, 2014).

Masking sounds consists of a continuous noise signal of 45 to 50 db(A) and are designed to mask irrelevant sounds by making the sounds, and above all the sounds boundaries, less audible (Banbury et al., 2001). Some masking sounds simulate a “babble effect”, i.e. the effect of a large number of voices, making individually voices indistinguishable, and have proven effective on diminishing the effect of irrelevant sounds on serial recall tasks (Banbury et al., 2001; Jones et al., 1995).

Based on the former literature on the attention capture effect and the looming effect it seems appropriate to make two assumptions. A ringtone with a sudden onset and decreasing volume will cause a greater attentional capture effect than the reverse because the abrupt onset is a greater difference from quiet than is a soft onset (Nöstl et al., 2014). On the other hand, a ringtone with an increasing volume could cause a looming sound effect, and thus call for the the participants’ attention in order to react to the simulated threat posed by the looming sound. By adding a masking noise background sound it is assumed that any potential attentional capturing effects will be diminished as it should make the irrelevant sounds less distinguishable and therefore less distracting. This experiment will test the foregoing hypotheses by exposing the participants to the two different ringtone conditions under a no mask and masking noise conditions.

3 Process and results

3.1 Process

3.1.1 Participants

Fifty students at the University of Gävle took part in the experiment in exchange for two cinema tickets. Due to misunderstanding task instructions two of the participants results were discarded with a total sum of 48 participants. All reported normal hearing and normal or corrected-to-normal vision. Participants comprised 27 females and 21 males (mean age = 24; age range = 20-37).

3.1.2 Apparatus and Materials

To-be-remembered items. The serial recall trials consisted of visually-presented to-be-remembered lists of eight digits from the set 1-8. The digits were arranged in a random order with the constraint that no ascending or descending runs of more than two digits occurred in a given list. The digits appeared one at a time in the central position of a computer display for 300 ms each with a 4500 ms interstimulus interval. Digits sustained a visual angle of about 2.6o (participants sat at approximately 50 cm distance from the screen).

The auditory tracks were processed by Florian Pausch at the Institute of Technical Acoustics at RWTH Aachen University and consisted of six combinations of audio tracks with quiet, masking noise, quiet with a fade in ringtone, quiet with a fade out ringtone, masking noise, masking noise with a fade in ringtone and masking noise with a fade out ringtone. The ringtone conditions (fade in, fade out) consisted of two wave files, lasting 300 ms (PCM, fs = 44.1 kHz, 16 bits). The quiet sound condition and noise condition consisted of looped 600 ms wave files (PCM, fs = 44.1 kHz, 16 bits).

Auditory sequences were presented via headphones at a sound level of approximately 65 dB(A). The experiment was executed on a PC with Windows 7 running an E-Prime 2.0 program (Psychology Software Tools) that controlled the serial recall trials and auditory distraction.

3.1.3 Design

A repeated-measures design was used with Sound (no noise, masking noise) and Ringtone (quiet, fade in, fade out) as the within-participant variables. Each participant received 72 trials (24 trials per condition). The test included 36 no noise trials, 36 masking noise trials, 12 no noise fade in ringtone, 12 no noise fade out ringtone, 12 noise fade in ringtone and 12 noise fadeout ringtone, 12 quiet trials and 12 noise only trials. The sound trials were randomly assigned within the blocks with the constraint that no distracter conditions were repeated twice in succession.

3.1.4 Procedure

The participants were informed via verbal and standard written instructions that any sound that they heard through the headphones was irrelevant to the task and that it should be ignored. Four quiet trials were delivered to participants to familiarize them with the serial recall task.

After the presentation of eight digits, the participants were presented with eight horizontally arranged boxes and the digits 1-8 and a question mark ("?") presented in a circular arrangement. In order to advance forward the participants then clicked the digits to re-create the serial order from the presentation. Because items remained in the circular array once selected, repetitions of the same item were possible, as with written recall. In case the participant didn't remember which digit to choose they could choose a digit again or the question mark to show they didn't remember.

3.2 Results

The participants responses were scored with serial recall standards: a chosen digit had to be in the same place in which it was presented during list presentation to be scored as correct. Figure 1 shows serial recall performance in each of the 6 [3(Ringtone) × 2 (Masking Noise)] conditions. The results are very clear-cut. In the no masking noise condition, there is evidence that a ringtone increasing in volume impairs serial recall performance more than a ringtone decreasing in volume and quiet. Moreover, the presence of masking noise eliminates the effect of the ringtone.

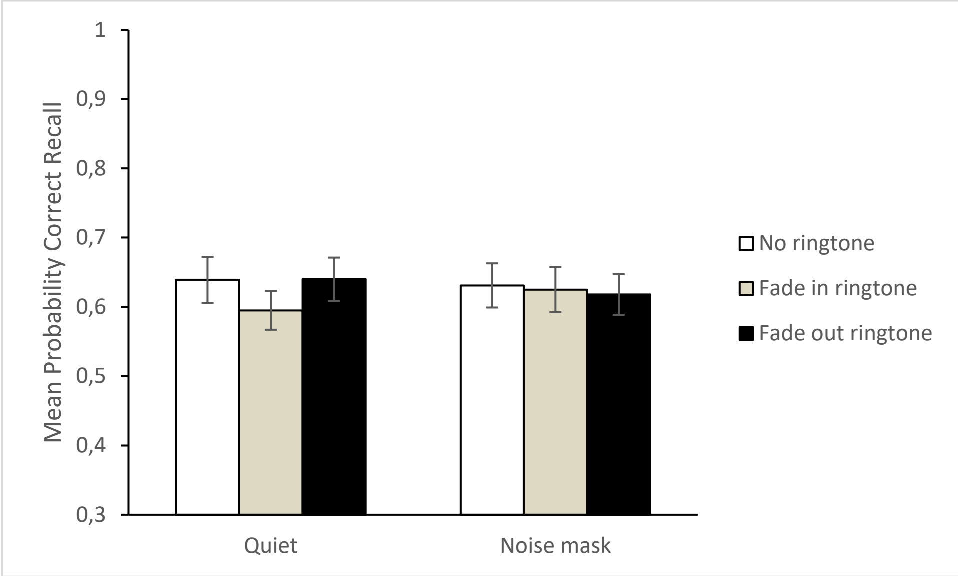

Figure 1. Mean Probability Correct Recall in different sound conditions. Standard error in error bars.

In a mixed Analysis of Variance (ANOVA), the main effect of Ringtone condition was significant, *F*(2, 94) = 3.78, *MSE* = .004, *p* = .026, η_p^2p2 = .075), and, while there was no main effect of Sound, *F*(1, 47) = .00, *MSE* = .004, *p* > .05, η_p^2p2 = .00), there was a significant interaction between Ringtone condition and Background sound condition, *F*(2, 94) = 4.54, *MSE* = .004, *p* = .013, η_p^2p2 = .088. This interaction was decomposed with Simple Effects Analysis (Least Significant Differences). This showed that against a quiet background, the increasing volume ringtone produced disruption relative to no ringtone (quiet; *p* = .004, 95% *CI* [.015, .074]) and decreasing volume ringtone (*p* = .002, 95% *CI* [.018, .074]). However, decreasing volume ringtone did not produce disruption compared with no ringtone (quiet; *p* = .9, 95% *CI* [-.025, .022]). In contrast, against a masking noise background, neither increasing volume ringtone nor decreasing volume ringtone produced disruption compared with noise without a ringtone (increasing volume ringtone compared with noise, *p* = .7, 95% *CI* [-.022, .032]; decreasing volume ringtone compared with noise, *p* = .3, 95% *CI* [-.038, .012]). Moreover, against a background of noise, increasing volume ringtone and decreasing volume ringtone did not differ from one another (*p* = .52, 95% *CI* [-.032, .016]).

A ringtone with an increasing volume (fade in) was more distracting than a ringtone with a decreasing volume (fade out). The decreasing ringtone did not affect serial recall performance compared with quiet, in comparison to the increasing ringtone. When masked by noise, however, the distracting effect of the increasing ringtone were eliminated.

4 Discussion

This study aimed to compare the effects of increasing and decreasing ringtones against each other and with no masking and masking noise backgrounds. On the one hand it was predicted that a ringtone with a sudden onset would be more distracting to serial recall because they differ more greatly from the expected auditory stimulation than a ringtone with a soft or gradual onset (Nöstl et al., 2014). On the other hand it was proposed that a ringtone that increased in volume would be more distracting than one that decreased in volume due to a looming effect (Neuhoff, 2016) whereby increasing ringtones yield the experience of an approaching object thereby triggering physiological, cognitive, emotional and behavioral responses that prepare the organism for potential danger associated with an approaching object (e.g., such as collision).

The results of the present research yielded evidence against the notion that ringtones produce disruption contingent on the degree to which they mismatch what is expected of the auditory environment (cf. Nöstl et al., 2014): The ringtone with sudden onset—and hence more different from the standard, quiet background, did not produce any distraction while the ringtone with gradual onset produced pronounced disruption of serial recall. However, the results gel neatly with the literature on the looming effect. The ringtone with soft onset and increasing volume gives the impression of an approaching sound and triggers an attentional capture mechanism, whereas the ringtone with sudden onset followed by decreasing volume gives is suggestive of a receding sound and is therefore not (as) attentionally capturing.

The presence of a masking noise background, however, successfully eliminated the effect of the increasing ringtone, or looming sound, as is inferred here. It is possible that masking sound reduced the perceptual processing of the range of pitch increase (from sudden onset to peak) necessary for the ringtone to be processed as looming. Therefore the ringtone lost its disruptive power. The successful counteraction effect of masking may be beneficial for attentional diversion effects to looming sounds within office environments within which cell phone ringing noises are commonplace.

One potential drawback from the study is that only used two different ringtones and therefore the generalizability of the results to other ringtones might be questioned. Some ringtones, for example, are more poorly localized than others and may not show a looming effect as pronounced as the one observed here. Furthermore, to fully explore the looming effect account of the results reported here one might manipulate the speed and perceived distance of looming and receding sound (Neuhoff, 2016). A fast approaching looming sound at close distance should, according to the looming account, produce more distraction than a slower looming sound at close proximity or a fast (or slow) looming sound at distance.

Moreover, to establish whether the inferred looming effect reported here is one of attentional capture or diversion, one should be able to demonstrate that other tasks that do not require a serial recall element should be disrupted (Jones & Macken, 1993). However, using the irrelevant sound paradigm (e.g., serial recall) in the current study is defensible since it is an established way to measure the impact of auditory distraction on focal task performance. It offers clear data and are not susceptible to a large variety of interpretations.

5 Conclusions

The results favor the idea that sounds with soft onset and increasing volume are perceived as looming (Neuhoff, 2016; Ingham et al., 2001; Wilson et al., 1998) and therefore capture more attention than those that have a sharp onset and falling volume . These latter sounds are likely perceived as receding. The results run contrary to the idea that sounds with sudden rather than soft onset are more attentionally capturing because they differ more greatly from what is expected given the previous pattern of auditory stimulation (cf. Nöstl et al., 2014). On the basis of prior research one might have expected the ringtone with sudden onset to capture attention from the serial recall task (Hughes et al., 2013; Vachon et al., 2016). However, the current study showed no reliable attentional capture effect for this condition. It is possible, although admittedly speculative, that the perception of a receding sound could act as a cue for the participant to (re)focus on the serial recall task.

From an evolutionary perspective, it is possible to argue that the looming sounds are objectively more urgent in sense of avoiding danger and therefore are more difficult to ignore (Neuhoff, 2016). McGuire et al's (2016) studies on the relation between cognitive load and looming effect bias showed that the looming effect bias is greater under high cognitive load (memorizing seven digits trials). These results are consistent with the effect of the increasing ringtones in the current experiment and could indicate that the auditory distraction of looming sounds is related to the cognitive load of the task performed. Further research on the potential moderation of the assumed looming effect by task load is required.

Interestingly, masking noise had a good capacity to reduce the attentional capture produced by looking sounds, presumably because it disrupted processing of the perceptual cues responsible for inferring movement. On the one hand these results may be interpreted as advocating the use of masking sounds in the office, since the mask here counteracted the detrimental effect of sound on cognition. However, on the other hand, participants often perceive the masking noise itself as disturbing.

The study demonstrates that increasing ringtones have a distracting effect on cognitive performance as measure via the serial recall task. Furthermore, the results suggest that where possible ringtone sounds that are can be perceived as looming should be avoided in the office setting so as to protect the productivity of workers. One way in which actual looming ringtones within the office might be reduced is by requiring participants to use phones at their work stations and cut down on the use of portable telephones.

5.1 Future Work

As touched upon in the foregoing, future research could possibly fashion sounds that can be perceived in 3D and therefore approach the head and pass overtop, while other sounds could approach the head and stop at the face. The latter should be more distracting since it potentially signals greater danger for the participant. Furthermore future research could also include variations on sounds with increasing volume such as simulating the sound from distant cubicles and against background speech, in order to simulate a work space environment and to further investigate whether looming effects emerge.

The present research has investigated different ringtone sounds effect on serial recall with digits. It would be advantageous to investigate the impact of ringtones on a broader array of cognitive tasks such as mental arithmetic tasks and memory for prose (Banbury and Berry, 1997; Banbury and Berry, 1998), or those requiring visual spatial memory for sequences and missing-item tasks. Results obtained from these tasks could address whether the looming effect, like other attentional capture effects, are noncontingent of the type of focal task executed (Hughes et al, 2007; Vachon et al., 2017). A further point of interest is that today's smartphones often incorporate sound coupled with vibration. It may be of interest, therefore, whether the sharp onset followed by decreasing vibration is less distracting than a gradual onset of vibration that increases in intensity. If the results are similar with the vibration manipulation than with the auditory manipulation then this might be some evidence against the looming account since unlike the auditory domain, such a manipulation in the vibrotactile domain conveys less spatial information. Clearly, there is a requirement for further research to be undertaken before making assumptions about the nature of the effect of increasing ringtone on cognitive performance reported here.

6 References

Baddeley, A. (1986). Working memory. Oxford psychology series, Oxford, UK.

Baddeley, A. (2003). Working memory: looking back and looking forward. *Nature Reviews Neuroscience, 4*(10), 829-839.

Baddeley, A., Eysenck, M. W., & Anderson, M. C. (2009). *Memory*. East Sussex.

Banbury, S., & Berry, D. C. (1997). Habituation and dishabituation to speech and office noise. *Journal of Experimental Psychology: Applied, 3*(3), 181.

Banbury, S., & Berry, D. C. (1998). Disruption of office-related tasks by speech and office noise. *British Journal of Psychology, 89*(3), 499-517.

Banbury, S. P., Macken, W. J., Tremblay, S., & Jones, D. M. (2001). Auditory distraction and short-term memory: Phenomena and practical implications. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 43*(1), 12-29.

Colle, H. A., & Welsh, A. (1976). *Acoustic masking in primary memory. Journal of verbal learning and verbal behavior, 15*(1), 17-31.

Cowan, N. (1998). *Attention and memory: An integrated framewor*k. Oxford University Press.

Edworthy, J., & Hellier, E. (2000). *Auditory warnings in noisy environments. Noise and Health, 2*(6), 27.

Edworthy, J., & Hellier, E. (2003). Urgency in speech warnings. In *RG de Jong, T Houtgast, EAM Fransten & WF Hofman, Proceedings of the 8th International Congress on Noise as a Public Health Problem* (pp. 65-69).

Edworthy, J., & Meredith, C. S. (1994). Cognitive psychology and the design of alarm sounds. *Medical Engineering & Physics, 16*(6), 445-449.

Hellier, E., Edworthy, J., Weedon, B., Walters, K., & Adams, A. (2002). The perceived urgency of speech warnings: Semantics versus acoustics. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 44*(1), 1-17.

Hughes, R. W., Hurlstone, M. J., Marsh, J. E., Vachon, F., & Jones, D. M. (2013). Cognitive control of auditory distraction: impact of task difficulty, foreknowledge, and working memory capacity supports duplex-mechanism account. *Journal of Experimental Psychology: Human Perception and Performance, 39*(2), 539.

Hughes, R. W., & Jones, D. M. (2003). Indispensable benefits and unavoidable costs of unattended sound for cognitive functioning. *Noise and Health, 6*(21), 63.

Hughes, R. W., Vachon, F., & Jones, D. M. (2007). Disruption of short-term memory by changing and deviant sounds: support for a duplex-mechanism account of auditory distraction. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 33*(6), 1050.

Ingham, N. J., Hart, H. C., & McAlpine, D. (2001). Spatial receptive fields of inferior colliculus neurons to auditory apparent motion in free field. *Journal of Neurophysiology, 85*(1), 23-33.

Jones, D. M., & Tremblay, S. (2000). Interference in memory by process or content? A reply to Neath (2000). *Psychonomic Bulletin & Review, 7*(3), 550-558.

Ljungberg, J. K., & Parmentier, F. (2012). The impact of intonation and valence on objective and subjective attention capture by auditory alarms. *Human Factors: The Journal of the Human Factors and Ergonomics Society, 54*(5), 826-837.

Macken, W. J., & Jones, D. M. (2003). Reification of phonological storage. *Quarterly Journal of Experimental Psychology Section A, 56*(8), 1279-1288.

McGuire, A. B., Gillath, O., & Vitevitch, M. S. (2016). Effects of mental resource availability on looming task performance. *Attention, Perception, & Psychophysics, 78*(1), 107-113.

Jones, D. M., & Macken, W. J. (1993). Irrelevant tones produce an irrelevant speech effect: Implications for phonological coding in working memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 19*(2), 369.

Jones, D. M., & Macken, W. J. (1995). Phonological similarity in the irrelevant speech effect: Within-or between-stream similarity?. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(1), 103.

Jones, D., Madden, C., & Miles, C. (1992). Privileged access by irrelevant speech to short-term memory: The role of changing state. *The Quarterly Journal of Experimental Psychology, 44*(4), 645-669.

Nöstl, A., Marsh, J. E., & Sörqvist, P. (2014). What we expect is not always what we get: evidence for both the direction-of-change and the specific-stimulus hypotheses of auditory attentional capture. *PloS one, 9*(11), e111997.

Neuhoff, J. G. (2016). Looming sounds are perceived as faster than receding sounds. *Cognitive Research: Principles and Implications, 1*(1), 15.

Röer, J. P., Bell, R., & Buchner, A. (2014). Please silence your cell phone: Your ringtone captures other people's attention. *Noise and health, 16*(68), 34.

Salamé, P., & Baddeley, A. (1982). Disruption of short-term memory by unattended speech: Implications for the structure of working memory. *Journal of verbal learning and verbal behavior, 21*(2), 150-164.

Shelton, J. T., Elliott, E. M., Eaves, S. D., & Exner, A. L. (2009). The distracting effects of a ringing cell phone: An investigation of the laboratory and the classroom setting. *Journal of environmental psychology, 29*(4), 513-521.

Stothart, C., Mitchum, A., & Yehnert, C. (2015). The attentional cost of receiving a cell phone notification. *Journal of experimental psychology: human perception and performance, 41*(4), 893.

Thornton, B., Faires, A., Robbins, M., & Rollins, E. (2014). The mere presence of a cell phone may be distracting. *Social Psychology*.

Vachon, F., Labonté, K., & Marsh, J. E. (2017). Attentional capture by deviant sounds: A noncontingent form of auditory distraction? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 43*(4), 622-634.

Wilson, W. W., & O'Neill, W. E. (1998). Auditory motion induces directionally dependent receptive field shifts in inferior colliculus neurons. *Journal of Neurophysiology, 79*(4), 2040-2062.

Wolfman, G. J., Miller, D. L., & Volanth, A. J. (1996, October). An application of auditory alarm research in the design of warning sounds for an integrated tower air traffic control computer system. *In Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 40, No. 19, pp. 1002-1006). Sage CA: Los Angeles, CA: SAGE Publications.

Wood, N. L., & Cowan, N. (1995). The cocktail party phenomenon revisited: attention and memory in the classic selective listening procedure of Cherry (1953). *Journal of Experimental Psychology: General, 124*(3), 24.