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Attentional capture by a looming ringtone

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Preface

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Abstract

Ringtones are a common distracting sound in modern workspaces. In an earlier experiment, ringtones increasing in volume (looming) produced greater attentional capture effect in the context of serial short-term memory, than ringtones with sudden onsets that decreased in volume (receding). To determine whether this effect occurred merely because the loudest part of the looming ringtone coincided with the most sensitive part of the serial short-term memory task, this study repeated the sound conditions of the first experiment, but altered their timing. In this study, the onset of the ringtones were brought forward in time such that the loudest part of the looming ringtone now coincided with the part of the serial short-term memory task wherein the onset of the looming ringtone occurred in the first experiment. The looming ringtone again produced more disruption than the receding ringtone, which failed to disrupt performance relative to the quiet control condition. The presence of a masking sound eliminated the looming ringtone effect, as in the previous study. The results here support previous work demonstrating that the looming sounds give rise to attentional capture and that this reflects an evolutionary adaptation to unconsciously react to approaching sounds/objects.

Keywords: Ringtones, Attentional capture, Looming effect, Irrational sound, Masking noise, Serial recall, Error management.

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1. Introduction

Ringtones are a common noise in human environments in the early 21th century. Ringtones are alarms designed to capture one's attention to the designated call. However, it may be argued that ringtones confer distraction, alerting individuals other than the owner of the cell phone. On the street, tube or café, the effects of ringtones may merely be annoying, but in a work environment such as an office or classroom, their distracting effect may have consequences for the work or learning of those unlucky enough to be recipients of the ringtone (Röer, Bell & Buchner, 2014). There are indications that phones have a distracting effect on their owners and the people in the surrounding environment (Röer et al., 2014; Stothart, Mitchum. & Yehnert, 2015). However, what is it about the acoustic characteristics of ringtones that cause distraction?

The human auditory perception system has evolved in order to detect immediate dangers in our environment (Banbury, Macken, Tremley & Jones, 2001). It is designed to react to changes in sound and this capacity is active at all times (Banbury et al., 2001, Tremblay & Jones, 2001; Hughes & Jones, 2003). While the sense of hearing could give an individual time to notice and react to a threat, it also poses the risk of auditory distraction, i.e. that sound can diminish or break one's concentration on tasks when subjected to task-irrelevant sounds in their environment (Banbury et al., 2001; Hughes & Jones, 2003).

Looming sounds, those that increase in volume, have proven to be especially effective at causing auditory distraction in humans, and other mammals. In several experiments, human subjects overestimated looming sounds when asked to measure their speed and distance (Neuhoff, Planisek & Seifritz, 2009; Neuhoff, 2016; McCarthy & Olsen, 2017). The looming effect has been shown in other mammals. Moreover, neurological activity associated with the looming effect has been reported in experiments with rhesus monkeys, guinea pigs and bats (Maier, Chandrasekaran & Ghazanfar, 2008; Maier & Ghazanfar 2007; Ingham, Heledd, Hart & McAlpine, 2001; Wilson & O'Neill, 1998). Looming sounds seem to cause a neurological reaction in the brain, urging the recipient to react to the threat of an approaching danger. Error management theory explains this tendency to make error by predicting that:

> *".. if judgments are made under uncertainty, and the costs of false positive and false negative errors have been asymmetric over evolutionary history, selection should have favored a bias toward making the least costly error."* (Haselton & Nettle, 2006, p. 2)

According to the duplex-mechanism account, there are at least two different ways that humans can be subjected to auditory distraction: irrelevant sound can directly affect the task the person is attending to (interference-by-process) or it can create a temporary distraction away from the task; attentional capture (Escera, Alho, Winkler & Näätänen, 1998; Hughes, Vachon & Jones, 2007; Hughes, 2014; Vachon, Labonté & Marsh, 2017). Interference-by-process is said to occur due to a conflict between cognitive processes, i.e. the irrelevant sound and focal task compete for the same, or similar, mental processes resulting in disruption of the focal task. As an example, the preattentive obligatory processing of changes within the auditory stream yield order information that conflicts with the deliberate ordering process – serial rehearsal – that underpins visual-verbal STM when humans are subjected to an irrelevant sound sequence that changes acoustically (Hughes, 2014).

In contrast, the attention capture mechanism causes subjects' attention to drift away from the focal task regardless of which process are involved (Wood & Cowan, 1995; Hughes, 2014; Vachon et al., 2017). The attention capture mechanism is triggered by sounds that deviate from the existing sound-pattern. Such unexpected changes cause a shift in attention away from the focal task, i.e. promote attention capture (Hughes, Hurlstone, Marsh, Vachon & Jones, 2013).

Looming objects have been a potential danger throughout human evolution and our senses have adapted in a way to deal with the threat (Neuhoff, 2016). This human (and mammal) tendency to mistake the looming sound for a threat could be less costly than the risk of ignoring potential danger and possibly endurance of harm (Haselton & Nettle, 2006; Haselton, Bryant, Wilke, Frederick & Galperin, 2009; Neuhoff, 2016). When subjected to a looming sound the amygdala and a neural network connected to attention and motor planning activates in order to respond to the threat in both humans (Neuhoff, 2016; Neuhoff, Planisek & Seifritz, 2009) and monkeys (Maier et al., 2007; Maier et al., 2008). This suggests that the reaction to looming sounds is an evolutionary trait (Neuhoff, 2016).

Auditory distraction is often studied with the irrelevant sound effect paradigm. This involves visually presenting participants with lists of 6-9 items (usually digits or letters) in a randomized order and requesting them to be recalled later in the same order. To remember the order of the items for the serial recall test, it is widely thought that participants use the process of serial rehearsal that involves the production of inner speech. At the same time as the to-be-remembered digits are being presented, the participant is subjected to irrelevant sounds, that he or she is told beforehand to ignore. The presence of irrelevant sounds tends to depress serial recall performance (Colle & Welsh, 1976; Banbury et al., 2001).

Earlier experiments have shown that the looming sound bias is greater when we are subjected to high cognitive work load (McGuire, Gillath & Vitevitch, 2017). In McGuire et al's study, subjects were requested to judge looming sounds and at the same time perform serial recall tests. When the researchers raised the number of to-be-remembered digits, the participants tendency to overestimate the looming sounds speed and distance increased, suggesting a tendency to overreact to looming sounds when put under high focal workload.

In order to make irrelevant sounds less audible it's possible to use continuous noise signals of 45 to 50 db(A), so called white noise. The noise mask simulates a large number of voices and the effect is commonly known as the "babble effect" (Banbury et al., 2001; Jones et al., 1995). White noise machines are used in offices for the purposes of masking background noise. As such it is interesting, as well as ecologically valid, to measure its effect on sounds from one speaker, like phone signals.

In my earlier experiment, the attention capture effect of ringtones with a sudden onset and decreasing intensity (receding) and ringtones with an increasing intensity (looming) were compared to a quiet condition and noise mask condition. Sound conditions were presented while subjects performed serial recall tests. While receding ringtones had no effect on serial recall as compared to quiet, looming ringtones impaired serial recall performance relative to quiet and to receding sounds. The experiment also demonstrated that the addition of a noise mask effectively blocks the disruption produced by the looming ringtone (Liljenberg, 2017).

While the results were clear cut, there is a potential confound in the design: The result could have occurred because the loudest part of the looming sound could have coincided with the most sensitive part of the task (e.g., serial position 5 in the task). To determine whether this was the case, or not, the current study repeated the sound conditions of the first study, but with one important difference. The onset of the sounds was brought forward in time such that the loudest part of the looming ringtone now coincided with where the onset of the looming ringtone had occurred in the first study. Like the first study, the potential impact of masking was once again studied: Looming and receding ringtones were either presented embedded in quiet, or in a noise mask. The study sought to determine whether changing the timing of the ringtones in relation to the serial recall task has a material effect on the apparent looming effect observed in the first study. If the disruptive effect of the looming ringtone disappears then the likelihood is that the additional disruption it produced relative to the receding ringtone, is not based on perceived looming, but is merely a consequence of high intensity sound impairing performance on the serial recall task because it coincides with a particularly susceptible portion of the task. On the other hand, if the same results are observed here as in the first study, then the perceived looming explanation of the results would appear to be the more likely explanation.

2. Method

2.1 Participants

The participants consisted of 47 students at the University of Gävle (21 females and 26 males, mean age = 26, age range = 19-44). They participated in exchange for two cinema tickets. All participants reported normal hearing.

2.2 Apparatus and Materials

To-be-remembered items. The participants were presented by visually-presented to-be-remembered lists of eight digits in a set of 1-8. The order of the digits was randomized, with the restriction that no more than two digits where presented in descending or ascending order in a given list. Each of the digits were presented in the middle of the monitor screen for 300 ms with a 4500 ms interstimulus interval. The visual angle of the digits was 2.60o and the participants were positioned at around 50 cm distance from the monitor. The serial recall test was executed with the application E-Prime 2.0 (Psychology Software Tools) on a PC with Windows 7.

The experiments six combinations of audio tracks were processed by Florian Pausch at the Institute of Technical Acoustics at RWTH Aachen University. The audiotracks consisted of quiet, masking noise, quiet with an ascending ringtone, quiet with a descending ringtone, masking noise with an ascending ringtone and masking noise with a descending ringtone. The audiotracks with ascending and descending ringtones consisted of two wave files, 300 ms long (PCM, fs = 44.1 kHz, 16 bits). The quiet and masking noise conditions consisted of looped 600 ms wave files (PCM, fs = 44.1 kHz, 16 bits).

The participants were subjected to the auditory sequences via headphones at sound levels of roughly 65 db(A). The auditory sequences were controlled by E-Prime 2.0 and the headphones connected to the PC.

2.3 Design

The experiment consisted of a repeated-measures design with Background sound (no noise, noise mask) and Ringtone (no ringtone, decreasing ringtone, looming ringtone) as within-participant variables. The serial recall test contained of 36 no noise trials (12 no noise decreasing ringtone, 12 no noise looming ringtone and 12 quiet trials) and 36 masking noise trials (12 noise decreasing ringtone, 12 noise looming ringtones, and 12 noise only trials). The different sound trials were assigned in a random order within the blocks. However, no distracter conditions were repeated twice in succession.

2.4 Procedure

Before each experiment session the participants were given verbal and written instructions that they should concentrate on the computer task and ignore any sounds they heard in the headphones. They were not allowed to take off their headphones until the experiment were finished. The serial recall test were simply explained by describing how a set of the digits 1-8 would be presented in a randomized order and that the participants task was to try to remember the order of the digits. It was explained that the participant could not adjust digits chosen by mistake and therefore had to ignore mistakes in the trials. It was also explained that if a participant left the test for some reason it would be considered interrupted and they could not return to finish it. Before the test started each participant were given 4 test trials to accustom themselves with the test.

Each trial consisted of a randomized presentation of the digits 1-8 presented in the middle of the monitor. Then there appeared 8 horizontally arranged boxes surrounded by the 8 digits and a question mark (?) in a circle. In order to advance the test forward the participant clicked on the digits to re-create the remembered order of the presented digits. Each item remained in the circle after being clicked on, making it possible to choose the same digit again. If not remembering a digit’s order, the participant could choose the question mark or the same digit again.

3. Results

The participants results were measured by serial recall standards: a correct digit had to be placed in the same order as in the list presentation. The performance in each of the 6 [2(Ringtone) x 2 (Masking Noise)] conditions are presented in Figure 1. The result shows that, under a quiet condition, a ringtone with an increasing volume impairs serial recall performance more than a ringtone with decreasing volume. Masking noise, however, effectively counteracted the distracting effect of the increasing volume ringtone.

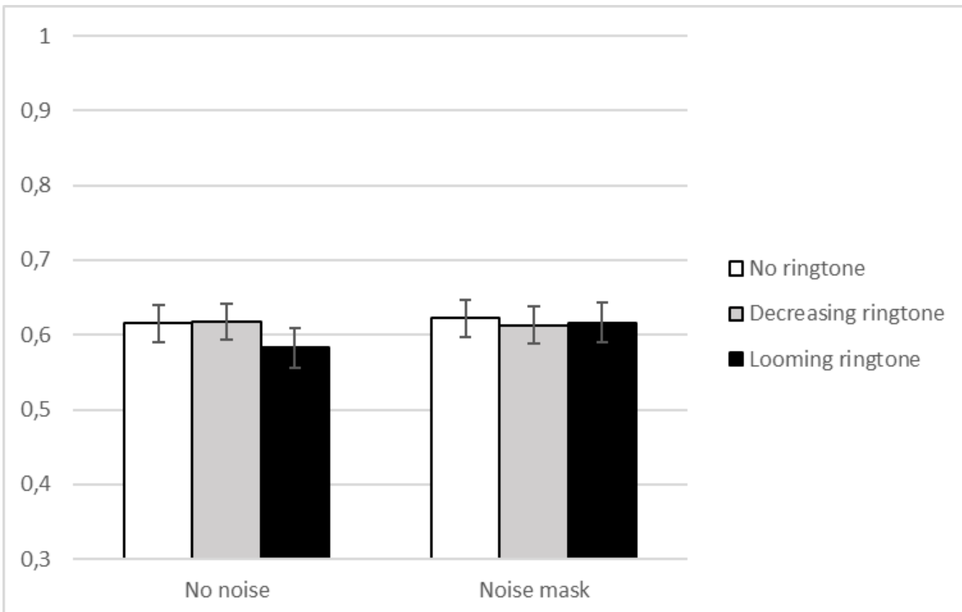

Figure 1. Mean Probability Correct Recall in different sound conditions. Standard error in error bars.

In a mixed Analysis of Variance (ANOVA), the main effect of Ringtone condition was significant $F(2, 92) = 1.30$, $MSE = .010$, $p = .045$, η_p^2p2 = .065). However, there was no main effect of Noise, $F(1, 46) = 3.21$, $MSE = .010$, $p >.05$, η_p^2p2 = .027). There was an significant interaction between Ringtone condition and noise, $F(2, 92) = 2.51$, $MSE = .009$, $p = .043$, η_p^2p2 = .052. Simple Effects Analysis (Least Significant Differences) was used to decompose the interaction. The Simple Effects Analysis demonstrated that the increasing volume ringtone caused disruption relative to no ringtone against a quiet background (quiet; $p = .002$, 95% CI [-.053, -.013]) and decreasing volume ringtone ($p = .006$, 95% CI [-.59, -.011]). The decreasing ringtone did not produce disruption compared to the quiet condition (quiet; $p = .85$, 95% CI [-.20, .024]). However, against a masking noise background, none of the ringtones produced disruption compared with noise without a ringtone (increasing volume ringtone compared with noise, p =

.67, 95% CI [-.032, .017]; decreasing volume ringtone compared with noise, p = .49, 95% CI [-.035, .021]). Moreover, with the noise masker, the increasing volume ringtone and decreasing volume ringtone were not significantly different (p = .78, 95% CI [-.021, .028]).

A looming ringtone (increasing sound) had a greater distracting effect than a ringtone with a sudden onset (decreasing sound) in a quiet background. When compared to a white noise background the distracting effect of the looming ringtone was extinguished.

4. Discussion

4.1 General discussion

This study aimed to replicate the effect of the first experiment (Liljenberg, 2017) to test if looming ringtones have a greater distracting impact than decreasing ringtones. In order to check if the results of the first experiment were a caused by the loudest part of the sound coinciding with the most sensitive part of the serial recall task, the timing of the onset of the ringtones was altered. The results of the present study demonstrate that the looming ringtone had a greater distracting effect on serial recall than the receding ringtone, suggesting against a non-looming account of the results. Like the first study, masking noise diminished the distracting effect of the looming ringtone, and therefore counteracted the attentional capture effect (Jones & Macken, 1995).

The current study, and that of Liljenberg (2017) relies on a method with an established form of measuring tool for auditory distraction (the irrelevant sound paradigm). The method creates clear data that doesn’t provide opportunities for different interpretation. The irrelevant sound paradigm gives result that have a good external validity, the tests ability to simulate distracting effects on focal ability is well accepted and it’s not presumptuous to assume that the results can be generalized to other settings with similar circumstances (Colle & Welsh, 1976; Banbury et al., 2001).

With verbal and written instructions have the possibilities of participant misunderstandings been minimized and under ongoing trials there were no observed distractions, breaks or other events that could have influenced the test results.

By using the same ringtones as in the earlier experiment (Liljenberg, 2017), this study has been able to show that the timing of the looming sound is not the reason for the looming ringtone's distracting effect. The processed ringtone sounds are easy to identify as ascending (looming) or receding and provides good material for future replication of the experiment.

4.2 Conclusions

The results clearly demonstrate that a looming ringtone has a greater attentional capture effect on serial recall than ringtones with a sudden onset with perception of receding. Receding ringtone do not disrupt serial recall at all. The results support the earlier study (Liljenberg, 2017) suggesting the looming sounds produce greater attentional capture than receding sounds. Moreover, the results of this study add new information about the capacity of looming sounds to cause attentional capture from an ongoing task (Neuhoff, Planisek & Seifritz, 2009; Neuhoff, 2016; McCarthy & Olsen, 2017). This ability of the looming ringtone to capture attention can be explained in error management theory by an evolutionary beneficial bias to react to looming objects to avoid danger (Haselton & Nettle, 2006; Neuhoff, 2016). In a natural environment looming sounds can be expected to be caused by approaching objects, and therefore there is greater benefit from overreacting to the looming sound, than not react and risk harm (Haselton & Nettle, 2006). However, in the modern environment digital sounds can be fashioned that give the perception of looming, but are stationary, such as ringtones used by smartphones.

One important point concerning this study—in relation to the looming effect—is that participants were told to ignore the ringtones while undertaking the serial recall trials. Therefore, the study shows that participants were unable to shut out or habituate to the looming ringtone over several trials. This result is in favor of the looming sound theory and of the looming sound effect as an evolutionary adaptation (Maier et al., 2007; Maier et al., 2008; Neuhoff, 2016; Neuhoff, Planisek & Seifritz, 2009). The result also shows that the looming effect is not just affecting our bias but also our ability for serial order processing.

The implications of the results are that there could be a negative effect of using ringtones with looming sounds in a workplace where work tasks requiring serial order processing, like arithmetic tasks and memory for prose, are executed (Banbury & Berry, 1997; Banbury & Berry, 1998). The effects on serial recall in this experiment are clear cut and in an office with many ringing phones it's probable that looming ringtones would affect the work of the employees. Furthermore the extent to which looming sounds may distract performance could be related to task-load since there is research suggesting that the looming effect is stronger when someone is subjected to a higher workload (McGuire, Gillath & Vitevitch, 2017). The results of the current study demonstrate that the distracting effects of ringtones on serial recall could be effectively diminished by masking noise or ignored in a work environment where many people talk simultaneously, i.e. creating a babble effect (Banbury et al., 2001; Jones et al., 1995). However, within quiet work environments, participants' attention would be extra sensitive to capture by looming ringtones.

4.3 Future Work

Future research should further explore the effect of looming sounds on different tasks requiring concentration, like missing-item tasks and visual spatial memory for sequences to see if the looming sound effect occurs regardless of the focal task executed (Wood & Cowan, 1995; Hughes, 2014; Vachon et al., 2017).

The attentional capture effect of looming sounds could also be further investigated by using 3D sounds, multiple speakers and processing of the sounds. Moreover, it would be useful to determine whether a change in the perceived speed of the sound could strengthen or weaken the looming effect depending on if the sound was simulating something approaching fast or slow (Neuhoff, Planisek & Seifritz, 2009; Neuhoff, 2016; McCarthy & Olsen, 2017).

5. References

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

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.

Escera, C., Alho, K., Winkler, I., & Näätänen, R. (1998). Neural mechanisms of involuntary attention to acoustic novelty and change. *Journal of cognitive neuroscience, 10*(5), 590-604.

Haselton, M. G., Bryant, G. A., Wilke, A., Frederick, D. A., Galperin, A., Frankenhuis, W. E., & Moore, T. (2009). Adaptive rationality: An evolutionary perspective on cognitive bias. *Social Cognition, 27*(5), 733-763.

Haselton, M. G., & Nettle, D. (2006). The paranoid optimist: An integrative evolutionary model of cognitive biases. *Personality and social psychology Review, 10*(1), 47-66.

Hughes, R. W. (2014). Auditory distraction: A duplex-mechanism account. *PsyCh Journal*, *3*(1), 30-41.

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.

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.

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.

Liljenberg, R. (2017) *A ringing phone: The distracting effect of ringtones*. (Unpublished master's thesis). University of Gävle, Gävle, Sweden.

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.

Macken, W. J., Phelps, F. G., & Jones, D. M. (2009). What causes auditory distraction?. *Psychonomic Bulletin & Review, 16*(1), 139-144.

Maier, J. X., Chandrasekaran, C., & Ghazanfar, A. A. (2008). Integration of bimodal looming signals through neuronal coherence in the temporal lobe. *Current Biology, 18*(13), 963-968.

Maier, J. X., & Ghazanfar, A. A. (2007). Looming biases in monkey auditory cortex. *Journal of Neuroscience, 27*(15), 4093-4100.

McCarthy, L., & Olsen, K. N. (2017). A "looming bias" in spatial hearing? Effects of acoustic intensity and spectrum on categorical sound source localization. *Attention, Perception, & Psychophysics, 79*(1), 352-362.

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.

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

Neuhoff, J. G., Planisek, R., & Seifritz, E. (2009). Adaptive sex differences in auditory motion perception: looming sounds are special. *Journal of Experimental Psychology: Human Perception and Performance, 35*(1), 225.

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.

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.

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.

Wood, N., & Cowan, N. (1995). The cocktail party phenomenon revisited: how frequent are attention shifts to one's name in an irrelevant auditory channel?. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 21*(1), 255.

Zivony, A., & Lamy, D. (2016). Attentional capture and engagement during the attentional blink: A “camera” metaphor of attention. *Journal of Experimental Psychology: Human Perception and Performance, 42*(11), 1886-1902.