EFFECTS OF STIMULUS TYPE ON EYE MOVEMENT MEASURES DURING MINDLESS READING AND MINDLESS LISTENING

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PLAGIARISM

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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ABSTRACT

"Mind wandering" refers to a state when attention is directed to internal thoughts unrelated to the sensations and perceptions of the immediate physical environment. Mind wandering occurs not only in passive situations but also during tasks that require attentional effort such as reading and listening. Despite its ubiquitous nature, the number of studies which examine mind wandering has increased only in the last few decades, particularly due to its subjective nature and spontaneous occurrence. Also, the majority of those studies focused on mind wandering during reading and investigated the differences between "mindless reading" and normal reading. To the best of our knowledge, there are no studies which examine mind wandering in different modalities, the effect of stimulus types on the frequency of mind wandering or contrast the behaviour of eyes under the effect of stimulus types during mind wandering. In this study, we analysed eye movements and pupil size in three conditions, that is, during only reading, only listening and simultaneous reading and listening, in three intervals preceding and following self-reported mind wandering episodes. The results of our study revealed that mind wandering frequency is not affected by stimulus type or cognitive load. The dominance of inner thoughts affects the frequency of mind wandering more than modalities, cognitive load and the demands of the here and now. Analysis of eye-tracking data showed that there are no differences in eye movements and pupil size between mindless and attentive states. However, while fixation duration and pupil size did not vary for modalities and intervals, the number of fixations were significantly higher during only reading than during listening. Thus, our study shows that the absence of any significant differences in fixation count and fixation duration between attentional states shows that a low-level processing of visual-lexical cues continues during mind wandering. These

results indicate a sensitivity to visual-lexical stimulus even in absence of conscious effort and an attentional decoupling mechanism in favour of visual-lexical stimulus.

Keywords: Attentional decoupling, eye tracking, meta-awareness, mind wandering, mindless listening, mindless reading

ÖZET

"Zihinsel gezinme", dikkatin dış dünyadaki uyaranlardan uzaklaşıp içsel düşüncelere ve bilinç akışına yönelmesine denir. Bu fenomen yalnızca kişinin pasif kaldığı durumlar sırasında değil, okuma ve dinleme gibi dikkat gerektiren görevler sırasında da ortaya çıkar. Günlük hayatta oldukça sık deneyimlendiği kanıtlanmış olmasına rağmen, özellikle içsel bir deneyim olması ve kendiliğinden ortaya çıkması nedeniyle zihinsel gezinmeyi ele alan bilimsel çalışmaların sayısında ancak son birkaç on yıldır artış gözlemlenmektedir. Ayrıca söz konusu çalışmaların büyük bir çoğunluğu okuma sırasında zihinsel gezinme fenomenine odaklanmış ve bu fenomen ile normal okuma arasındaki farklılar üzerine yoğunlaşmıştır. Farklı modaliteler sorasında zihinsel gezinmeyi konu edinen veya farklı uyaran türlerinin zihin gezinmesi sıklığı ve göz hareketleri üzerindeki etkilerini araştıran hiçbir çalışma bulunmamaktadır. Bu çalışmada, yalnızca okuma, yalnızca dinleme ve hem okuma hem dinlemeden oluşan üç görev sırasındaki göz hareketlerini ve gözbebeği genişlemesini, meta-farkındalık öncesi ve sonrasındaki üç farklı zaman aralığı içerisinde inceledik. Çalışmamızın sonuçları, zihinsel gezinme sıklığının uyaran türlerine ve bilişsel yüke göre farklılık göstermediğini ortaya koydu. Elde ettiğimiz sonuçlara göre, baskın içsel düşünceler, zihinsel gezinme sıklığı üzerinde modaliteler, bilişsel yük ve mevcut fiziksel uyaranlardan daha fazla etkiye sahiptir. Göz takip tekniği analizlerimiz, göz hareketlerinin ve gözbebeği boyutunun zihinsel gezinme ve normal dikkat durumunda farklılaşmadığını gösterdi. Ancak okurken zihinsel gezinme deneyimi sırasındaki fiksasyon sayısının dinlerken zihinsel gezinme sırasındaki fiksasyon sayısından istatistiksel olarak fazla olduğunu bulduk. Böylece sonuçlarımız, zihinsel gezinme sırasında görsel-dilsel bilginin bilişsel işlenişinin alt-düzeyde devam ettiğini göstermiştir. İnsan zihni, bilinçli bir çabanın eksikliğinde dahi görsel-dilsel uyaranlara

karşı bir hassasiyet göstermekte ve görsel-dilsel uyaranların lehine bir dikkat ayrışması mekanizması oluşturmaktadır.

Anahtar kelimeler: Göz takibi, dikkat ayrışması, dinleme sırasında zihinsel gezinme, okuma sırasında zihinsel gezinme, üstbilişsel farkındalık, zihinsel gezinme

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION

In 1925, Hugo Gernsback invented “the Isolator”, an out-of-the-box solution, with the aim of avoiding and eliminating environmental distractions to focus his attention fully on a task at hand. Apparently, Gernsback believed that the utmost challenge to his attentional resources was those distractions such as noise, light and smell coming from the immediate physical environment, and isolating himself from those would be the sole and exclusive remedy. However, studies show that human mind itself, which has a high capacity to ignore irrelevant or inapplicable information while perceiving physical entities (Faber et al., 2012) and to sustain the needed attention in goal-directed tasks (Ko et al., 2017; Boksem et al., 2005), can be a major distractor. That is, attention is affected and interrupted not only by environmental distractors but also by the mind itself in the form of thoughts and images.

Mind interrupting and deviating itself from external sensory inputs or a given task has been given many different names in the literature such as “daydreaming, fantasy, task-unrelated thought, stimulus-independent thought, self-generated mental activity and zoning-out”; however, as Callard et al. (2013) put it in their review, the use of a more inclusive term “mind wandering” has increased drastically since 2006. In this thesis, we will follow the steps of Smallwood and Schooler, who contributed greatly to the literature, and refer to the phenomenon in question as “mind wandering” (Smallwood and Schooler, 2006).

1.1. Mind Wandering

On daily basis, humans need to use attentional mechanisms to perceive their environment, to decide what behaviour or way of thinking to embrace based on the

percept they generate and to behave accordingly. Also, there are tasks such as planning, critical thinking and problem solving that require more attentional effort in addition to some high-level cognitive processes such as reading for comprehension that a regular human can execute without extraordinary effort throughout their entire lives. All of these significant processes seem to be so automatic and easy that humans tend to think their minds are always actively involved in the immediate environment and mindful during these processes. However, introspective reports of individuals and scientific data suggest the opposite: Our minds wander almost half of the time. To be more precise, while earlier research showed that our minds wander 30% of daily life (Kane et al., 2007), a more recent study which included a huge number of 2250 adult participants indicated that mind wanders mindlessly 46.9% of waking hours (Killingsworth and Gilbert, 2010).

The phenomenon of wandering mind refers to an internally-directed attentional state which involves trains of thought shifted from the sensations and perceptions of the immediate physical environment (Kam and Handy, 2013). Although the intermittent cycles of mind wandering are ubiquitous for everyone, the capacity to catch the self in mind wandering episodes varies, such that these episodes sometimes may go unnoticed (Schooler et al., 2004). On the other hand, an individual's self-awareness that their mind has wandered is called "meta-awareness" in literature, a term that refers to "one's explicit knowledge of the current contents of thought" (Schooler et al., 2011).

1.2.Mindless Reading

Besides its ubiquity, what makes this phenomenon quite a striking object of scientific curiosity is that people often report "zoning out" not only in passive situations such as waiting in a queue or travelling in a passenger seat but also during

actions and different sensual modalities such as reading and listening that require attentional effort (Smallwood et al., 2008). Wandering mind during reading is called "mindless reading". Mindless reading refers to a state in which people suddenly become aware of thinking about something else other than the text even though their eyes continue moving across the text. They may even flip to the following page (Mills et al., 2021, Rayner and Fischer, 1996). Since the second half of 1980s, a vast number of studies have investigated mindless reading, especially the differences between normal and mindless reading. Yet, there are still gaps in mindless reading research.

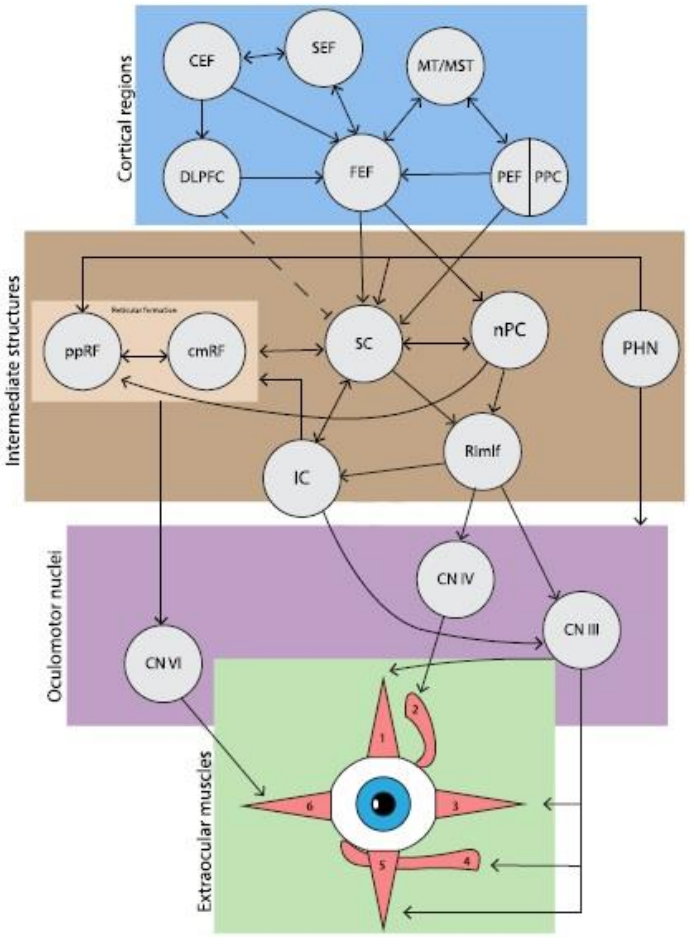
The main reasons behind the aforementioned gap are the subjective nature and spontaneous occurrence of mind wandering, which is a rather internal state, difficult to detect freely from self-reports (Mills et al., 2021; Tusche et al., 2014). To address and eliminate these challenges, a number of scientists turned to eye-tracking technique, which provides objective measures of the behaviour of eyes. The majority of eye-tracking studies examined the differences in eye movements during normal and mindless reading and revealed such important measurement standards regarding eye movements that some of the recent research started to focus on the on-line detection of mindless reading using eye-tracking data as it occurs (Mills et al., 2021; Brishtel et al., 2020; Steindorf and Rummer, 2020; Gwizdka, 2019).

1.3.Eye-Tracking in Mindless Reading Research

Eye-trackers are video-based devices which are used to record eye motion, gaze location and pupil diameter in time during a task "by measuring the position of the corneal reflection of an infrared light relative to the pupil" (Carter and Luke, 2020). Thanks to their high temporal resolution, they provide real-time, moment-to-moment objective measures of the behaviour of eyes as an experimental tool. Studies revealed that the link between the nervous system, the cognitive processes and both the

position and duration of gaze and pupil dilation are directly and highly connected (Carter and Luke, 2020; Rayner, 1998) (see Figure 1). Also, the changes in eye movements and pupil dilation are "largely outside of conscious control" (Carter and Luke, 2020). This means that fixations, saccades and pupil size are biological markers which are based on lower-level mechanisms that exceed the capacity of conscious control (Rayner, 1998). Thus, eye-trackers offer a reliable tool for many fields such as language, attention, perception and decision-making studies. Particularly in language studies, there are measurement standards concerning eye movements in reading now thanks to eye-tracking technologies.

Figure 1
"The oculomotor network" by Carter & Luke (2020)



Note. The figure represents the tight connection between cortical regions and oculomotor nuclei and extraocular muscles.

The standards mentioned above include both local eye movement measures such as fixation duration, fixation count, total viewing time and pupil size and global eye movement measures such as words fixated, off-text fixations and regressions. Studies showed that eye movements are affected by low-level lexical variables such as word identification. For example, Franklin and colleagues (2011) observed a strong relationship between the lexical properties of words and the time allocated to process them. In addition, high-level variables such as frequency of words, ambiguity, semantic context and predictability of words also affect both spatial and temporal eye movements. For instance, words that have a low frequency of occurrence are fixated longer than the words with high higher frequency of occurrence (Liversedge et al., 1998), and words which are highly predictable from the prior sentences enhance the use of the parafoveal information (Balota et al., 1985).

In the light of the aforementioned standards, studies were conducted to examine the differences in eye movements between normal reading and mindless reading. The results of previous studies indicate that mindless reading episodes show a lack of moment-to-moment cognitive lexical and linguistic processing which normally guides eye movements during reading (Reichle et al., 2010, Uzzaman and Joordens, 2011). However, although the mind wanders in internal thoughts unrelated to the text during this state, eyes still move across the page (Reichle et al., 2010), and word identification still proceeds in the absence of conscious effort (Schooler et al., 2004). More importantly, according to “the level of inattention hypothesis” (Schad et al., 2012), readers are very sensitive to low-level errors such as word-recognition and syntactic parsing in episodes of weak mindless reading.

However, there is still little consensus on some of the measures. We believe that the lack of consensus in literature results mainly from the inconsistency of

preferred time intervals that have been examined. Additional factors may be the method of catching the wandering mind episodes (probe-caught and self-caught) and the presentation type of the stimuli used.

This lack of consensus on the differences in eye movement measures between mindless reading and normal reading has started to catch more attention recently, particularly after Reichle et al.'s study which formed a basis with its detailed eye-tracking data analysis comparing six internals within a total of 120 seconds before both self-caught and probe-caught mind wandering during reading. In their paper, Steindorf and Rummel (2020) addressed to the lack of consensus in question and presented a comparison of previous studies (see Figure 2).

Figure 2

The table of "Studies comparing eye movements during self-categorized episodes of mindless reading (MR) versus normal reading (NR)" (Steindorf & Rummel, 2020).

	Reichle, Reineberg, and Schooler (2010)	Smilek et al. (2010)	Uzzaman and Joordens (2011)	Foulsham, Farley, and Kingstone (2013)	Frank, Nara, Zavagnin, Touron, and Kane (2015)
Task characteristics					
N	4	12	22	26	29
Reading materials	*Sense and Sensibility*	Two passages of *A Short History of Nearly Everything*	16 pages from *War and Peace*	120 single sentences	Five chapters from *War and Peace*
Reading duration	13.5 h (average)	Up to 30 min		30 min	
Probe count	151.5 (average)	20	10 (average)	9 (average)	20
Area of interest	2.5-s, 5-s, 10-s, 30-s, 60-s, and 120-s intervals preceding thought probes	5-s intervals preceding thought probes	5-s intervals preceding thought probes	Target sentences	3- to 8-s intervals preceding thought probes
Eye-movement measures					
Fixation count	MR = NR (first-pass fixations)	MR < NR	MR = NR	MR > NR	MR = NR (first-pass fixations)
Fixation duration	MR = NR (first-fixation durations)	MR = NR	MR = NR	MR > NR	
Between-word regression count	MR = NR			MR = NR	MR > NR
Within-word regression count			MR < NR		
Blink count		MR > NR	MR = NR		MR > NR
Reading time	MR > NR (gaze duration & total viewing time)			MR > NR	MR = NR (gaze duration)
Word-frequency effect				MR < NR	

1.4. Comparison of Eye Movements during Mindless Reading and Normal Reading

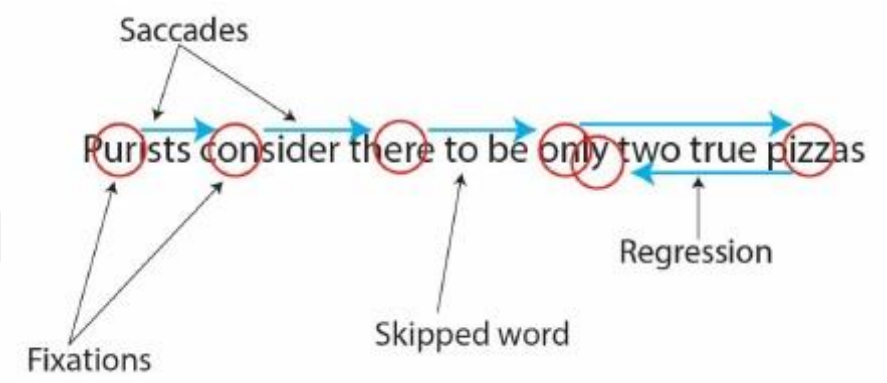
1.4.1. Fixation Count

Figure 3 shows examples of fixations, saccades, skipped words and regressions during a reading task. As it can be concluded from the figure, a fixation is a stable landing of the eye on a word to extract information. During reading, people do not fixate on each word in a sentence because information processing is not limited to the foveal vision. People skip some words as they can obtain information from the following word which is in the parafoveal vision. Studies revealed that fixations can be affected by "a variety of factors such as the nature of the visual stimuli, the task's purpose and complexity, and the skill and attention of the individual" (Carter and Luke, 2020). In general, more fixation count is associated with more attention to, interest in or confusion about stimuli.

On the comparison of number of fixations during mindless and normal reading, Reichle et al. (2010) revealed that participants made fewer fixations during mindless reading episodes than during episodes of normal reading in 2.5s-intervals. However, the same trend was not present during the intervals of 5s, 10s, 30s, 60s and 120s. In the same year, Smilek, Carriere and Cheyne (2010) obtained results which presented fewer fixations during mindless reading in 5s-interval. To replicate these results, Uzzaman and Joordens (2011) conducted an experiment for 5s-interval and revealed that although the results showed the same trend, results were only marginally-significant (p = .079). By contrast, in a study which examined the number of fixations while reading exact same sentences during mind wandering and normal reading revealed that there were only slightly-marginal significant more fixations in mindless reading episodes (p = .09) (Foulsham et al., 2013).

In general, the consensus is that mindless reading exhibits less fixations, and this is shown as an implication that eye movements become “less affected by lexical and linguistic variables” (Reichle et al., 2010) and “reading becomes less effortful and more automatic” during mindless reading (Uzzaman and Joordens, 2011).

Figure 3
Fixations, saccades, skipped words and regression by Carter & Luke (2020)



1.4.2. Fixation Duration

Fixation duration refers to the time people spend fixating on a particular location. Like in the case of fixation count, longer fixations are generally associated with more attention to, interest in or confusion about the stimuli. Longer fixations during reading imply more cognitive engagement and are associated with more time and effort for comprehension (Uzzaman and Joordens, 2011).

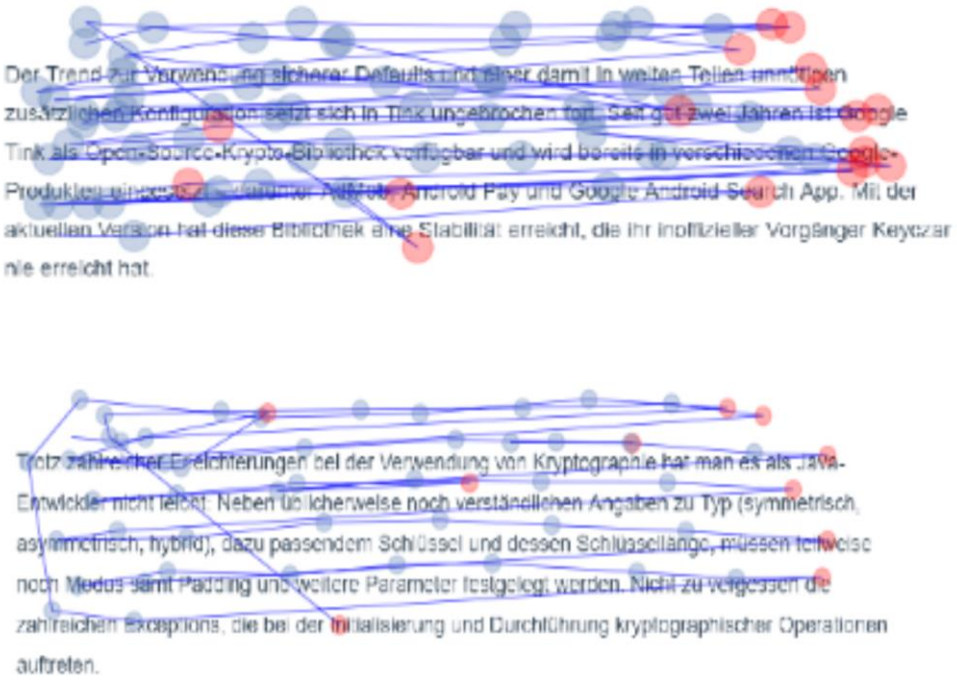
On the differences in fixation duration between mindless reading and normal reading, previous experiments which used more a naturalistic page-by-page reading task revealed that there were no significant differences between episodes of mindless reading and normal reading in 2.5s and 5s intervals (Smilek et al., 2010; Uzzaman and Joordens, 2011, Rayner and Fischer, 1996). The interpretation of those results by Rayner and Fischer (1996) was that “fixation durations resembled those of the reading times” during mindless reading.

However, according to the results of Reichle et al.'s study (2010), fixations were longer during mindless reading. Similarly, Foulsham et al.'s study (2013), which presented a text as a single-sentence-by-page paradigm, showed that average fixation duration during mindless reading was longer than in normal reading. Based on the results of their study, Reichle and his colleagues (2010) concluded that "cognitive processes that guide eye movements during normal reading are not engaged during mindless reading". These results imply that, for future studies, it is worth taking into consideration that inconsistency lies not only in the findings but also in how the stimuli were presented.

Figure 4 shows a sample of the visualisation of the eye-tracking data during mindless reading and mindless reading (Brishtel et al., 2020).

Figure 4

"Eye movements during the reading task" by Brishtel et al. (2020)



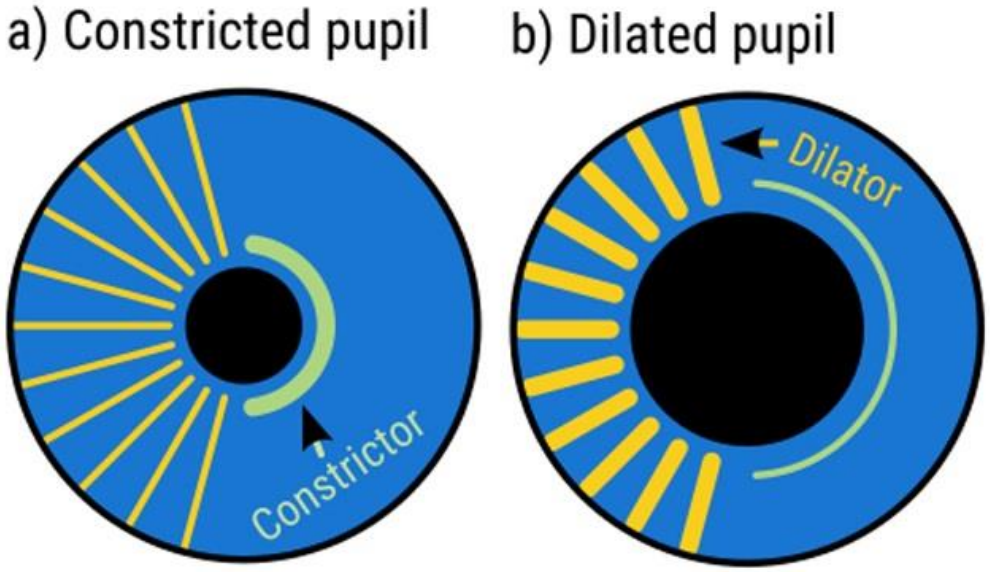
Note. "Fixation points are in blue and regression points are in red. Top: Paragraph with reported mind wandering. Bottom: Paragraph with focused reading behaviour."

1.4.3. Pupil Size

The changes in pupil size called constriction and dilation (see Figure 5) occur as a response to not only the changes in luminance of the external stimuli but also the nature of cognitive processes. Factors such as cognitive load and mental effort, attentional and motivational shifts, arousal, surprise, emotional factors and affective states also lead to changes in pupil diameter, so pupillometry offers a rich marker of many mental processes (Einhäuser, 2017). For example, Engelhardt, Ferreira and Patsenko (2010) examined pupil diameter of participants while being exposed to conflicting prosody and visual context simultaneously to increase cognitive load. The results of the study showed that cognitive load increased pupil diameter significantly. In a study in which participants read series of proverbs and regular sentences, Fernández et al. (2016) revealed that while memory load increases pupil diameter, predictability of words decreases it.

Yet, the number of studies which contrasted pupil diameter during mindless reading and normal reading is little, and the findings of those studies are inconsistent. In general, according to Smallwood et al. (2011), pupil diameter either does not react to external stimuli or shows abnormal changes. Uzzaman and Joordens (2010) presented participants pages of a text and revealed that pupil size did not show significant variations during mindless reading than normal during. On the other hand, Franklin et al. (2013) conducted a word-by-word reading task. The results of their study showed higher pupil dilation during mindless reading than during on-task reading. We believe the fact that inconsistency lies not only in the findings but also in how the stimuli were presented should be taken into consideration for future studies.

Figure 5
Pupil constriction and dilation by Mathôt (2018)



1.5. Costs of Mindless Reading

Studies regarding the phenomenon of wandering mind suggest that task-unrelated thoughts during a task are detrimental to performance quality, and reading is not an exception in that regard. A number of studies showed that mindless reading episodes have negative effects on overall text comprehension and information processing (Mooneyham and Schooler 2013; Unsworth and McMillan, 2013; Sanchez and Naylor, 2018; Mills et al., 2021). More intriguingly, Sanchez and Naylor's results (2018) manifested that more mind wandering during reading also increases misunderstandings and generates more incorrect associations.

1.6. Mindless Listening

There are only few studies which investigate mind wandering during listening. Although there are a number of studies examining "passive listening" and "inattentive listening", they all fail in paraphrasing mind wandering during listening, which we will refer to as "mindless listening" in this study. The reason of this failure is that these phrases do not necessarily underline attentional resources drawn away from a

task to inner thoughts. To be more precise, while Liao et al. (2018) and Lester and Vecera (2018) define passive listening as listening by "not involving in a task" Hendrikse et al. (2019) uses the term of passive listening for "a condition in which no target was specified". Likewise, Prey (2019) defines "inattentive listening" as "background listening" and "lean back listening" while Pasupathi & Rich (2005) refer to it as "distracted" and "unresponsive" listening which lack attentive cues such as eye contact, facial expressions, comments or responses. So, only "inattentive listening" bears some similarities to mindless listening but the only similarities between mindless listening and inattentive listening are lack of overt bodily response and comprehension (Pasupathi and Rich, 2005).

One of few studies which investigate mindless listening analysed the effects of music familiarity and mind wandering during a word-relatedness task (Feng and Bidelman, 2015). The study revealed that unfamiliar music increased the frequency of mind wandering episodes more than familiar music or neutral environmental sounds. Taruffi et al. (2017) investigated the effect of sad and happy music on mind wandering and found that listening to sad music was associated with more spontaneous inner thoughts. On the effect of emotions triggered by music on mind wandering, Brishtel et al. (2020) presented sad and happy music during a reading task. The results of the study showed that the combination of familiar context and sad music resulted in most frequent off-task thoughts, and, also, the presence of music increased the mind wandering frequency during reading.

To the best of our knowledge, there are no studies which examine eye movements during only mindless listening or compare eye movements during mindless listening and mindless reading.

1.7. Aim and Hypothesis

In the light of previous studies mentioned above, the present study bears various aims. First of all, we aim to contribute to the examination of mind wandering, which started to get more scientific attention only in the past few decades, by addressing to the inconsistency of the results of previous studies. Secondly, we aim to fill an important gap in the literature. To the best of our knowledge, there are no studies which compare the effect of stimulus types on the frequency of mind wandering or contrast the behaviour of eyes under the effect of stimulus types during mind wandering. Also, one of our main goals is to reveal detailed information about eye movements during mindless listening. Our last motive is that since there are only few studies which presented the changes of pupil size during mind wandering, we aim to replicate existing data.

To that end, we will add auditory lexical and simultaneously-presented visual and auditory lexical stimuli to our experimental design in addition to visual lexical stimulus, which was the only stimulus type examined in earlier studies (Uzzaman and Joordens, 2011; Reichle et al., 2010; Schooler et al., 2004; Rayner and Fischer, 1996; just to name a few). In addition, we aim to achieve a naturalistic reading task setting by presenting the stimuli page-by-page in contrast to previous studies which present stimuli word-by-word (Franklin et al., 2011) or sentence-by-sentence (Foulsham et al., 2013). To boost a naturalistic task setting, we will utilize a best-seller novel, which does not require topic experience or prior knowledge.

Our hypotheses are as follows: (1) Eye movements will display sensitivity to visual-lexical stimuli even in absence of conscious effort with more fixations and longer fixation duration during mindless reading. With regards to this argument, we expect to reveal (2) an attentional decoupling mechanism in favour of visual-lexical

stimulus during simultaneously-presented visual- and auditory-lexical stimulus but (3) no differences in number of fixations or fixation duration between mindless and normal attentional states and (4) a similar pattern of eye movements for two conditions with visual-lexical stimuli. With the same token, (5) the number of zone-outs is expected to be more for listening. Also, (6) changes in pupil size will differ for mindless and normal states due to the effects of information processing and cognitive load. Lastly, (7) zoning-out frequency will affect overall comprehension accuracy negatively.

2. METHODS

2.1. Participants

31 subjects (20 females and 11 males) between the ages of 18 and 39 (*M* = 24,129; *STD* = 5,76) participated in the experiment in Computational Neuroscience and Visual Perception Laboratory at Yeditepe University. All subjects were native Turkish speakers with normal or corrected-to-normal vision and with no history of attention or reading disorder. None of the participants were familiar with the material used in the study. Participants signed a consent form prior to the experiment. The study was approved by the Science-Ethics Committee of Yeditepe University.

2.2. Apparatus

A Gazepoint GP3 eye tracker (CNVP Lab, Yeditepe University, Istanbul, Turkey) monitored the gaze and pupil size of participants binocularly. The eye tracker has a 60-Hz sampling rate. Participants viewed the stimuli on ASUS VG278H 27" monitor screen with 16:9 ratio and 120Hz refresh rate. The eye-tracking camera was 60 cm and the monitor for around 70 cm from participants' eyes. Chin and forehead rests were used to minimize head movements and ensure comfort. Participants listened to the auditory stimuli using Sennheiser M2 AEi on-ear headphones. We conducted the experiment on MatlabR2022a coder program.

2.3. Materials

Participants read and/or listened to the first three parts of the first chapter (*M* = 33.09 pages) of *Crime and Punishment* by Fyodor Dostoyevsky in Turkish (1866/2021). The audio version of the novel was acquired from the application called Storytel.

To evaluate their comprehension accuracy following the experiment, participants were asked to answer the questions of a comprehension test. Participants were also asked to fill out a Zoning-Out Questionnaire, both prepared by the researcher.

The comprehension test was a three-alternative multiple-choice test with 14 questions (see Appendix A). It aimed to assess the average comprehension accuracy of participants. The Zoning-Out Questionnaire was a 21-item five-point Likert scale questionnaire (see Appendix B). It aimed to obtain responses about participants' mind wandering experience. The five-point scale ranged from 0 ("never") to 4 ("always").

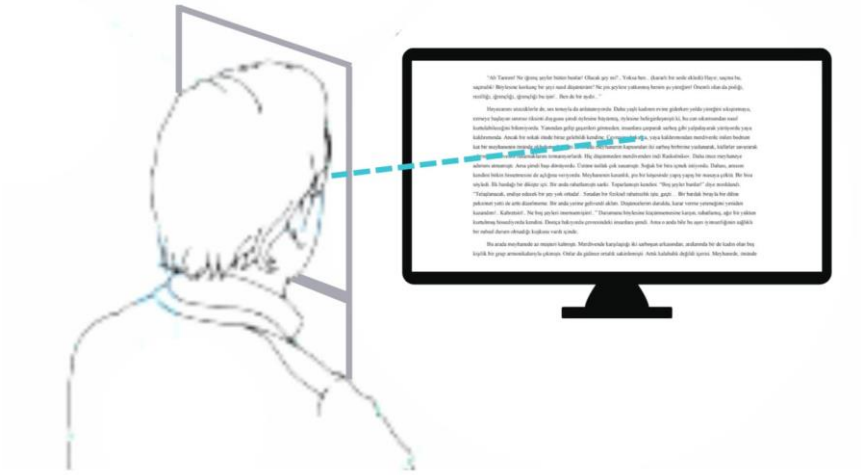
2.4. Stimuli

Three different stimuli were prepared on Adobe Premiere Pro from the material *Crime and Punishment* in Turkish. Participants viewed the stimuli on an ASUS VG278H 27'' with 16:9 ratio and 120Hz refresh rate 3D monitor. The screen size was 1920x1080 pixel (643x460mm). Participants listened to the auditory stimuli using Sennheiser M2 AEi on-ear headphones. The experiment was coded in MATLAB.

2.4.1. Visual-Lexical Stimulus Only

Visual-Lexical Stimulus Only was a uni-modal condition in which participants only read the text presented on the monitor at their own pace (see Figure 6). The text was presented in 14-point Times New Roman typeface with a line spacing of 1.5. The text was presented page-by-page on a monitor. Each page consisted a maximum of 19 lines. Participants pressed the "M" key to move forward through the text.

Figure 6.
Experimental setup for the "Visual-Lexical Stimulus Only" Condition



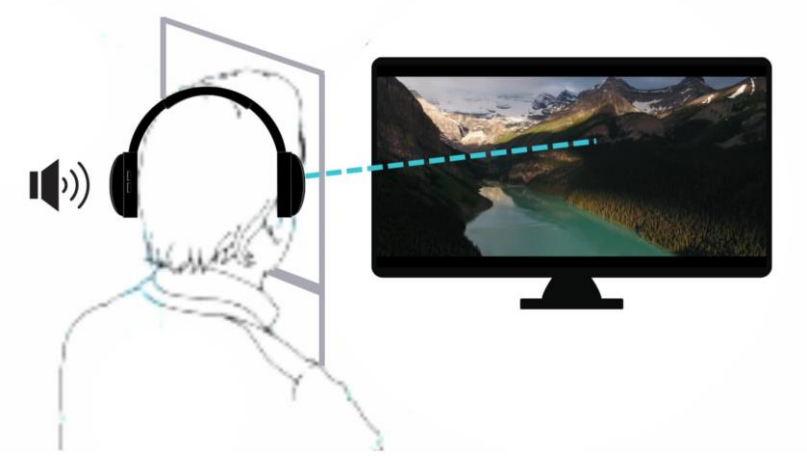
Visual-Lexical Stimulus Only
"Only Reading"

2.4.2. Auditory-Lexical Stimulus Only

Auditory-Lexical Stimulus Only was a uni-modal condition in which participants only listened to the text through a headphone (see Figure 7). To avoid off-screen fixations and eye-shutting, we presented a drone-shot video of a natural scenery rather than a blank screen.

To ensure that the video used would not affect the eye movements of participants, we chose a slow-motion video in which the scenery was almost static and there were very little changes in visual markers such as colour, the size of the objects and perspective. Also, studies show that eye movements during listening exhibit variations mirroring the conceptual structure of auditory-lexical differences independently from visual inputs. To set an example, Huette et al. (2014) observed shorter fixations and dispersed saccades while listening to "past progressive" forms, which represent in-progress actions, than during listening to "past simple" forms, which represent the end of an action.

Figure 7
Experimental setup for the "Auditory-Lexical Stimulus Only" Condition



Auditory-Lexical Stimulus Only
"Only Listening"

2.4.3. Visual- and Auditory-Lexical Stimuli Simultaneously

Visual- and Auditory-Lexical Stimuli Simultaneously was a dual task in a multi-modal setting in which participants listened to the text while reading it simultaneously (see Figure 8). The text was presented in 14-point Times New Roman typeface with a line spacing of 1.5. The text was presented page-by-page on a monitor. Each page consisted a maximum of 19 lines. As we synchronized the audio version and the flips to the pages, it was not a self-paced reading task.

Figure 8
Experimental setup for the "Visual- and Auditory-Lexical Stimuli Simultaneously" Condition.

Visual- and Auditory-Lexical Stimuli Simultaneously
"Listening while Reading"

2.5. Procedure

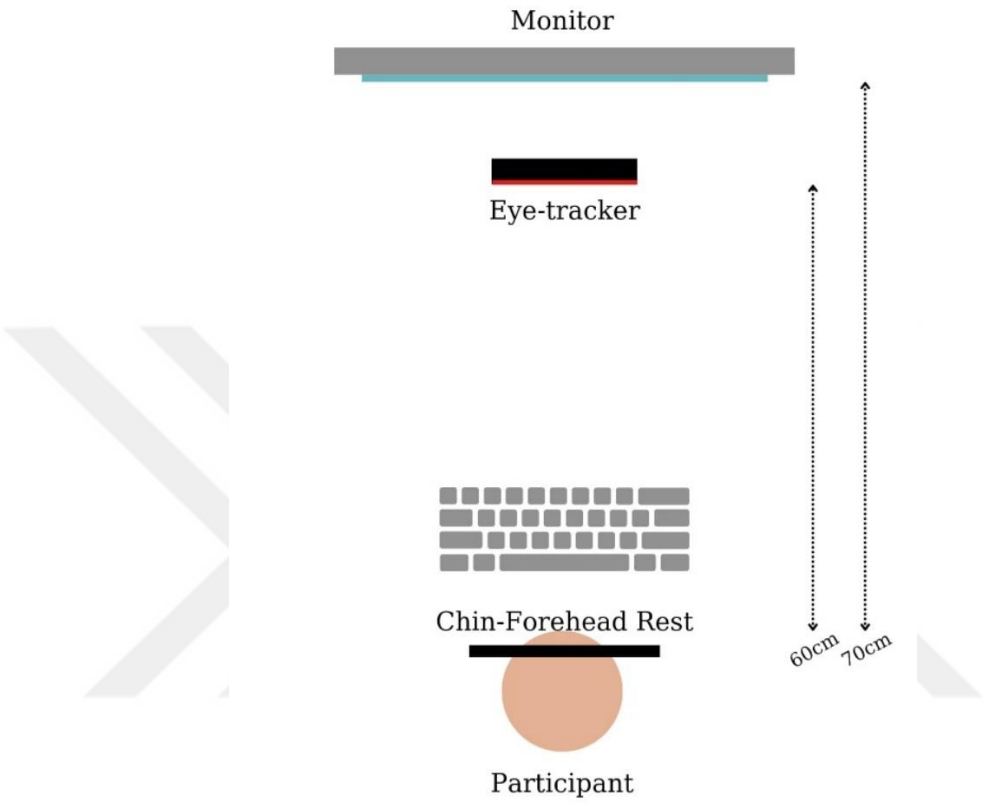
We conducted a 2x3x3 factorial experiment to test the effects of three different stimulus types and time intervals on two different levels of attentional states, namely, mind wandering and attentive state.

In the experiment, each participant took part in all of the three experimental conditions across 20- to 21-minute-long sessions (M = 19.9) before a monitor in a darkened testing room. The eye-tracker recorded the x and y positions of the gaze of both eyes and the pupil diameter. The distance between participants' eyes and the eye-tracking camera and the monitor was 60cm and around 70cm respectively (see Figure 9). Each session began with the calibration of the eye-tracker with a 5-point calibration and a 5-point validation. In our experiment, we used self-caught reporting method in which participants pressed a key on the keyboard to express the moment of meta-awareness following a zone-out. Before the experiment, participants were familiarized with the definition of zoning out: "At some point during the task, you realize that you have been thinking about something else, not about the task at hand." In all sessions, we asked participants to press "Z" key whenever they caught themselves zoning out. Between each condition, participants took 5-minute breaks. After each break, we repeated the calibration. After the experiment, participants were asked to answered comprehension questions and fill out a zoning-out questionnaire. The entire experiment took around 90 minutes.

We changed the order of the Visual-Lexical Stimulus Only and Auditory-Lexical Stimulus Only sessions to avoid any effect of mental or physical fatigue or boredom. Half of the participants first only read the text in the first session, then read and listened to the text simultaneously in the second session and finally only listened to the audio in the third session. The other half of the participants first listened to the

audio in the first session, then read and listened to the text simultaneously in the second session and finally only read the text in the third session.

Figure 9
Bird's eye view of the experimental setting



2.6. Data Analysis

2.6.1. Data Cleaning and Pre-Processing

To ensure reliability and to normalize the data, we conducted some pre-processing steps before analyses. Firstly, we cleaned each participant's continuous eye-tracking coverage from the data of the calibration run.

Before identifying the intervals that we would analyse, we checked the time period between each self-reported zone-out. Because in the majority of studies which used "probe-caught" method to detect mind wandering, participants were probed in every 2-3 minutes (Sanches and Naylor, 2018; Uzzaman and Joordens, 2011). This is because previous studies showed that periods of mind wandering can extend 1 to 2

minutes in duration (Reichle et al, 2010). Thus, we set measures for the intervals that would be extracted for the analyses accordingly. We identified the self-reported zone-outs which had a minimum of 60 seconds before and after the previous and next reported zone-out to eliminate overlapping among intervals.

Then, we extracted the data spanning 10 seconds both prior to and following the self-reported zone-outs from each participant's continuous record of eye-tracking data. Then, the total 10-second data spans were divided into three individual intervals (2.5 seconds, 5 seconds and 10 seconds). The intervals prior to the zoning-outs were "mindless-state" data, and the intervals following the zoning-outs were "attentive-state" data, which is referred to as "normal" in most of the previous studies. Thus, 2.5s interval corresponded to the minimal time span immediately before and after the zone-outs (see Figure 10).

Figure 10

Representation of defined attentional states and individual intervals

Next, we excluded the individual data point which corresponded to the exact meta-awareness moment as it was interrupted by participant's pressing key to report zoning-out, and we also excluded the individual data in any interval which extended into another interval (Reichle et al., 2010).

For the analyses of fixation count and fixation duration, we first conducted validity check on FPOGV, which provides the validity of the point-of-gaze. We

discarded the intervals with less than 50% validity rate in each interval from the analyses as we had further strict pre-processing steps. Then, we filtered FPOGD, which shows the duration of fixations in seconds since fixation durations less than 80ms are discarded as outliers in eye-tracking studies (Reichle et al., 2010).

For the analysis of average pupil size, we used LPUPILD data, which provides the diameter of the left eye pupil in millimetres. To ensure normalization, we standardized the pupil diameter estimates of the eye-tracker through the computation of z-score for each participant (Mills et al., 2021).

Due to absence of reported zone-outs during at least one condition, the data of four participants were removed from analyses. We also removed the data of two subjects from analyses, which failed to have 60s between each zone-out. Thus, the number of participants designated for average pupil size analysis was 25. Also, we discarded the fixation duration data of one participant as its validity rate was less than 50%. So, the number of participants designated for fixation count and duration analyses was 24.

2.6.2. Data Analysis

We analysed participants' eye movements and pupil size during each interval both prior to and following self-reported zone-outs on JASP statistics program. We used the same statistics program to examine the effects of stimulus types on zoning-out frequency and the relation between comprehension accuracy and zoning-out frequency.

To examine differences in the number of fixations and fixation duration during three conditions as a function of attentional states and intervals, we used the validated and filtered FPOGD data. We analysed data from each interval using repeated measures analyses of variance (ANOVAs). We also conducted Mauchly's sphericity

test and nonparametric testing due to small sample size. Based on the results of Post-Hoc Bonferroni Correction which showed significant or marginally significant difference (all *p*s ≤ .066), we used two-tailed matched sample t-tests (paired samples t-tests). Shapiro-Wilk normality test was applied, and if normality was not proved, we applied nonparametric Wilcoxon signed-rank.

One of the necessary measures taken for the analyses of numbers of fixations and fixation duration was to run separate ANOVAs for the 10s interval since it was longer and had naturally more fixations than 2.5s and 5s intervals.

Next, with the aim of examining differences in pupil size during three stimulus types as a function of attentional states and intervals, we used the computed z-scores of LPUPILD. We analysed data from each interval using repeated measures analyses of variance (ANOVAs). We also conducted Mauchly's sphericity test and nonparametric testing due to small sample size. Based on the results of Post-Hoc Bonferroni Correction which showed significant or marginally significant difference ($p \leq .053$), we used two-tailed matched sample t-tests (paired samples t-tests). Shapiro-Wilk normality test was applied. If normality was not proved, we applied nonparametric Wilcoxon signed-rank.

Herein, it is worth highlighting that since the luminance of the video presented during Auditory-Lexical Stimulus Only condition was not in harmony with the luminance of the texts presented during other conditions, we analysed participants' pupil size during Auditory-Lexical Stimulus Only condition separately.

Additionally, to examine if there are any significant differences in the numbers of zone-outs for different stimulus types, we conducted repeated measures analyses of variance (ANOVAs) with Post-Hoc Bonferroni Correction. We also conducted Mauchly's sphericity test and nonparametric testing due to small sample size.

Finally, we aimed to examine the relation between the independent variable of zoning-out frequency and dependent variable of comprehension accuracy. To that end, we applied correlation and linear regression analysis with pairwise Shapiro-Wilk normality test.

3. RESULTS

3.1. Behavioral Results

Table 1 shows a number of behavioural measures across all participants, including the mean measures of the duration of conditions, the total number of pages completed by participants, participants' overall comprehension accuracy in answering stimuli-related questions and the number of time participants caught themselves zoning-out during each condition.

Table 1
Mean Behavioural Measures

Measure	*M*	*STD*
Duration of conditions (minutes)	19,99	0,61
Number of pages	33,09	3,51
Comprehension accuracy (%)	73,34	21,66
Number of zone-outs in Only Listening Task	8,42	7,27
Number of zone-outs in Only Reading Task	7,67	7,11
Number of zone-outs in Listening While Reading Task	7,45	7,45

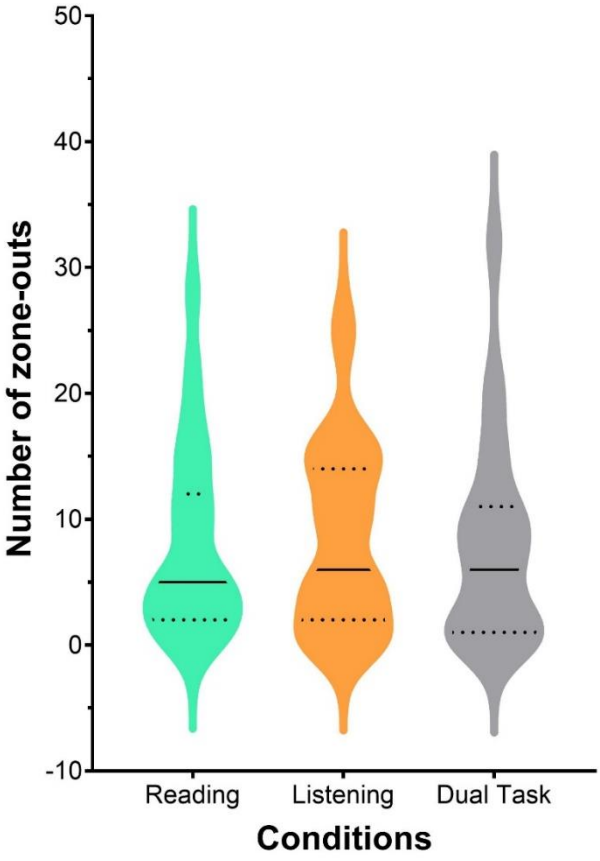
Note. Values in parentheses show the scale of the measures.

3.1.1. Analysis of Mind Wandering Frequency Across Conditions

In general, participants reported self-caught zone-outs 0 to 32 times during the experiment. The number of total zone-outs varied across conditions. As Figure 11 indicates, the condition with only auditory stimulus showed the highest mind wandering frequency (M = 8,42). While the condition with visual lexical stimulus showed the second highest mind wandering frequency (M = 7,67), the condition with simultaneously-presented auditory and visual lexical stimuli showed the lowest (M = 7,45). By contrast, the number of maximum zone-outs was the highest during the dual task condition. However, Post-Hoc tests revealed that there were no significant differences in frequency between any of three conditions (F = 0,648, p = .49). Our

results showed that stimulus type had no significant effect on the frequency of mind wandering.

Figure 11
Number of zone-outs during conditions

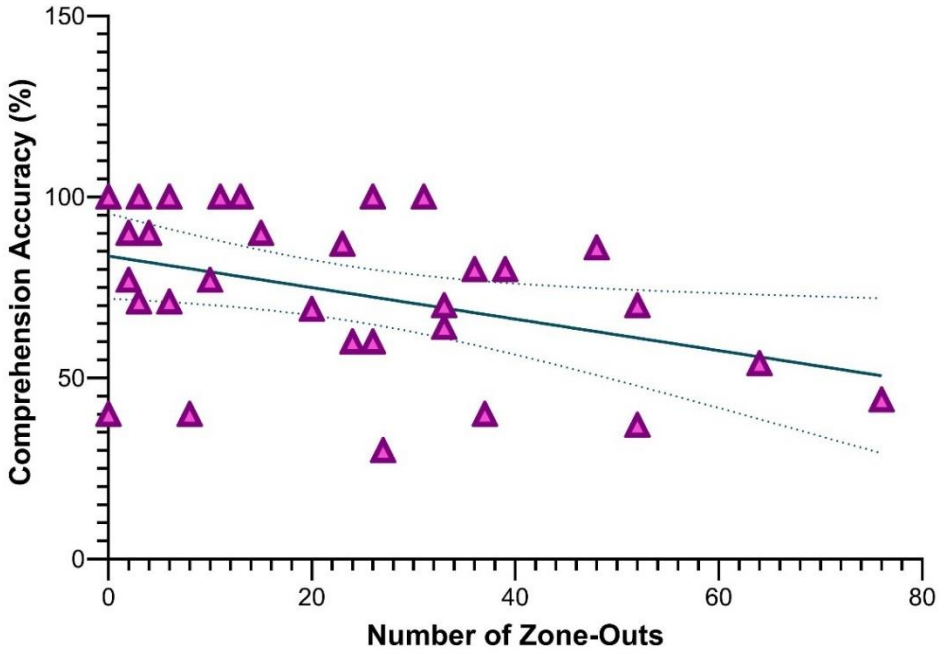


3.1.2. Analysis of the Relation between Comprehension Accuracy and Mind Wandering Frequency

On average, participants responded to 74% of the comprehension questions correctly, which demonstrates that they understood what they read and listened to. Results of correlation and linear regression analysis showed a medium-magnitude negative correlation between comprehension accuracy and mind wandering frequency (Pearson's r = -0,397, p = .027) (see Figure 12).

Figure 12

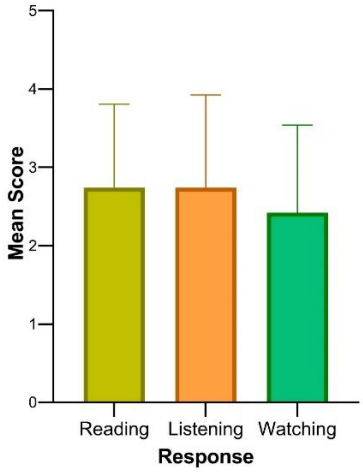
The relationship between zoning-out frequency and comprehension accuracy



3.1.3. Analysis of the Experience-Sampling Data

Figure 13 represents participants' responses to one of the questionnaire questions which reads as "How much do these activities make you zone out?". Firstly, we conducted repeated measure ANOVAs, and Post Hoc tests revealed no significant difference between options. Secondly, we checked to see if participants' self-reports would match their actual mind wandering frequencies during each condition. Results of correlation analysis showed a high-magnitude positive correlation between the responses of participants and their actual mind wandering frequency during reading (Pearson's $r = 0.623$, Spearman's rho & Kendall's tau-b $p = <.001$) and listening (Pearson's $r = 0.587$, Spearman's rho & Kendall's tau-b $p = <.001$). Yet, the correlation between the responses and actual mind wandering frequency was only marginally-significant for dual task (Pearson's $r = 0.412$, Spearman's rho $p = .059$, Kendall's tau-b $p = .055$). (For more figures, see APPENDIX C)

Figure 13
Results of zoning-out questionnaire

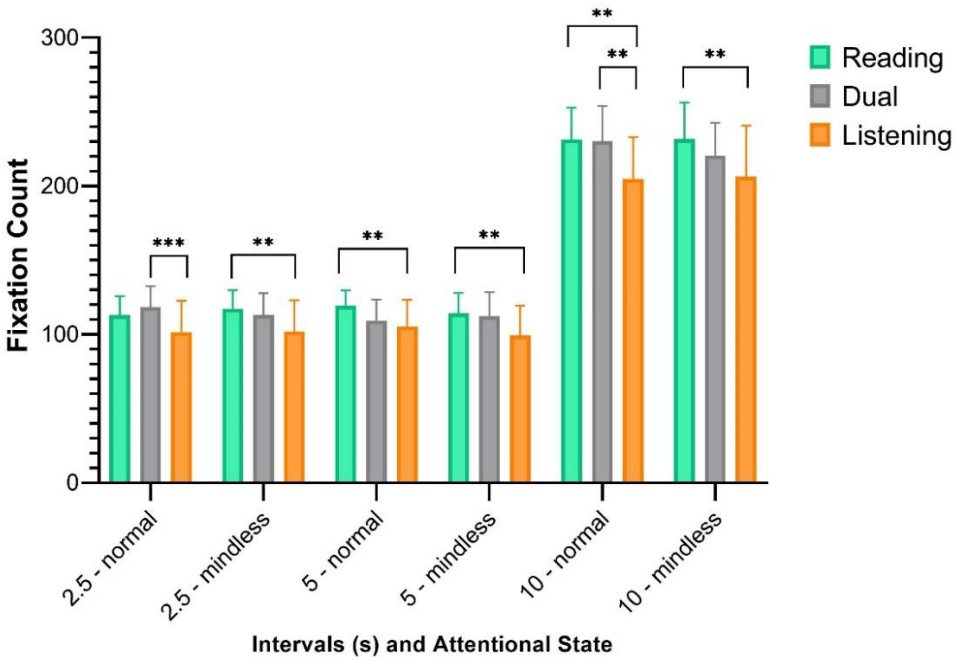


3.2. Results of the Eye-Tracking Analysis

3.2.1. Fixation Count Results

Figure 14 shows the mean numbers of fixations during three conditions (reading, listening and dual task) as a function of attentional states (mindless or normal) and the intervals (2.5s, 5s or10s).

Figure 14
Mean fixation count measures within each interval during three conditions as a function of attentional states



Note. Significant differences are indicated (**p < .01, ***p < .001).

The contrasts demonstrated that there were more fixations during normal dual task (t = 4.708, p = <.001, Cohen's d = 0.982) than during normal listening in the 2.5s interval after zone-outs. The fixations during normal dual task in 2.5s interval after zone-outs were the highest (M = 118.435) while the fixations during normal listening in 2.5s interval after zone-outs were the lowest (M = 101.565). In mindless state, there were more fixations during mindless reading (t = 3.341, p = .003, Cohen's d = 0.697) than during mindless listening in the 2.5s interval preceding zone-outs. The fixations during mindless reading in 2.5s interval preceding zone-outs were the highest (M = 117.304) while the fixations during mindless listening in 2.5s interval preceding zone-outs were the lowest (M = 102). There were no significant differences between reading and dual stimuli types either in mindless or normal states in 2.5s intervals preceding and following the zone-outs.

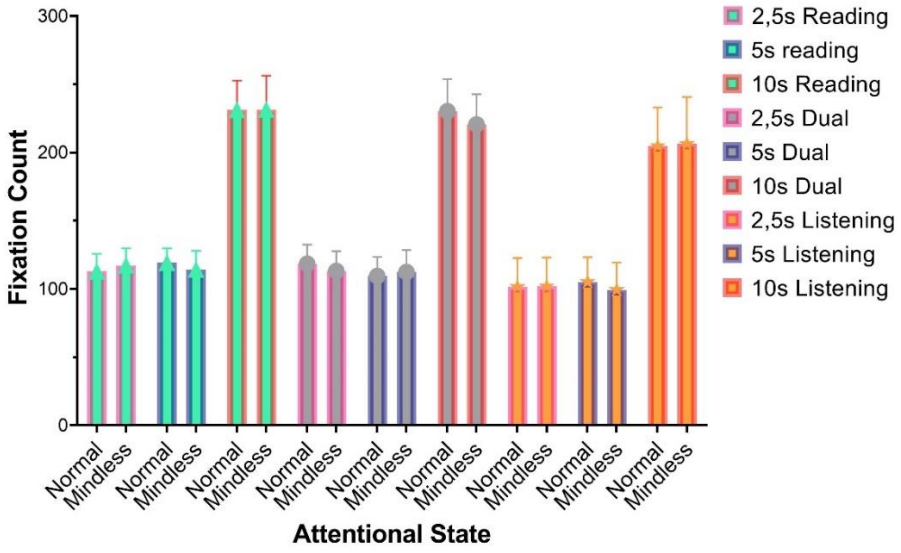
During 5-second interval, there were more fixations during normal reading than during normal listening (t = 3.748, p = .001, Cohen's d = 0.782). The fixations during normal reading in 5s interval after zone-outs were the highest (M = 119.348) while the fixations during normal listening in 5s interval after zone-outs were the lowest (M = 105.261). In mindless state, there were more fixations during mindless reading (t = 3.116, p = .005, Cohen's d = 0.650) than during mindless listening in the 5s interval prior to self-reported zone-outs. The fixations during mindless reading in 5s interval preceding zone-outs were the highest (M = 114.261) while the fixations during mindless listening in 5s interval preceding zone-outs were the lowest (M = 99.391). There were no significant differences between reading and dual stimuli types either in mindless or normal states in 5s intervals preceding and following the zone-outs.

During 10-second interval, there were more fixations during normal reading (t = 3.629, p = .001, Cohen's d = 0.757) and normal dual task (t = 3.732, p = .001, Cohen's d = 0.778) than normal listening. The fixations during normal reading in 10s interval after zone-outs were the highest (M = 131.348) while the fixations during normal listening in 10s interval after zone-outs were the lowest (M = 204.826). In mindless state, there were more fixations during mindless reading (t = 2.900, p = .008, Cohen's d = -0.605) than during mindless listening in the 10s interval prior to self-reported zone-outs. The fixations during mindless reading in 10s interval preceding zone-outs were the highest (M = 231.565) while the fixations during mindless listening in 10s interval preceding zone-outs were the lowest (M = 206.478). There were no significant differences between reading and dual stimulus types in both normal and mindless states during 10s intervals preceding and following the zone-outs.

However, analysis of the differences of number of fixations during the same interval and the same stimulus type across attentional states demonstrated no significant results (see Figure 15).

Figure 15

Mean numbers of fixations during intervals across stimulus types as a function of attentional states



3.2.2. Fixation Duration Results

Figure 16 shows the mean numbers of fixations during conditions (reading, listening or dual) as a function of interval length (2.5s, 5s or10s) and attentional states. Results of repeated measures ANOVAs yielded no significant difference between conditions in any of the intervals.

Figure 16
Mean fixation duration measures in milliseconds for stimulus types as a function of attentional states and intervals

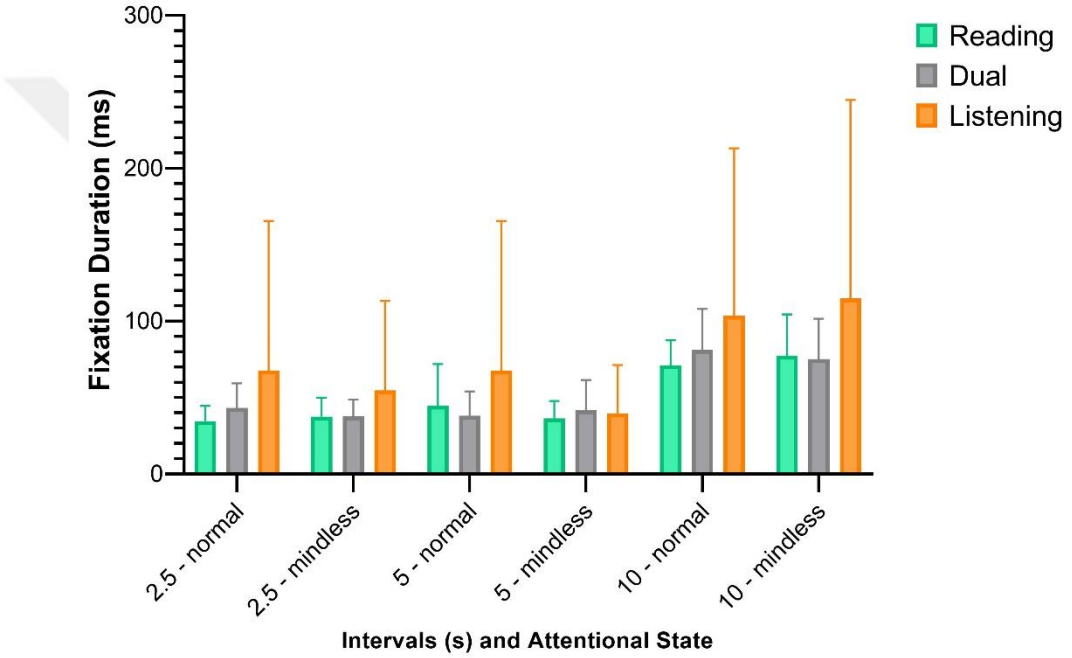
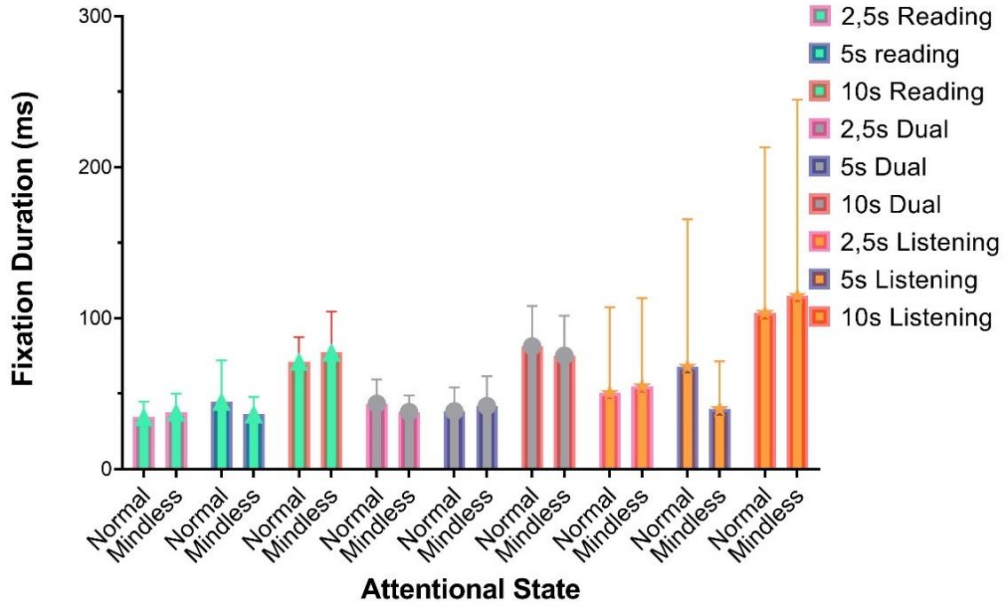


Figure 16. Mean fixation duration measures in milliseconds for stimulus types as a function of attentional states and intervals.

Figure 17 shows the mean numbers of fixations during conditions (reading, listening or dual) and intervals (2.5s, 5s or10s) as a function of attentional states (mindless or normal). Results of Post Hoc tests revealed no significant difference between conditions in any of the intervals.

Figure 17

Mean fixation durations in milliseconds as a function of attentional states across interval lengths and stimuli types



3.2.3. Pupil Size Results

Because of the luminance inharmony, we analysed the data of Auditoy-Lexical Stimulus Only separately.

Figure 18 shows the mean pupil size in millimetres for the three intervals (2.5s, 5s and 10s), two stimuli (only reading task and dual task) and two attentional states (mindless or normal). Post Hoc tests did not yield any significant mean effects of stimuli type, intervals or attentional states on pupil size.

Figure 18

Mean pupil size measures during Reading and Dual Task conditions as a function of interval length and attentional states

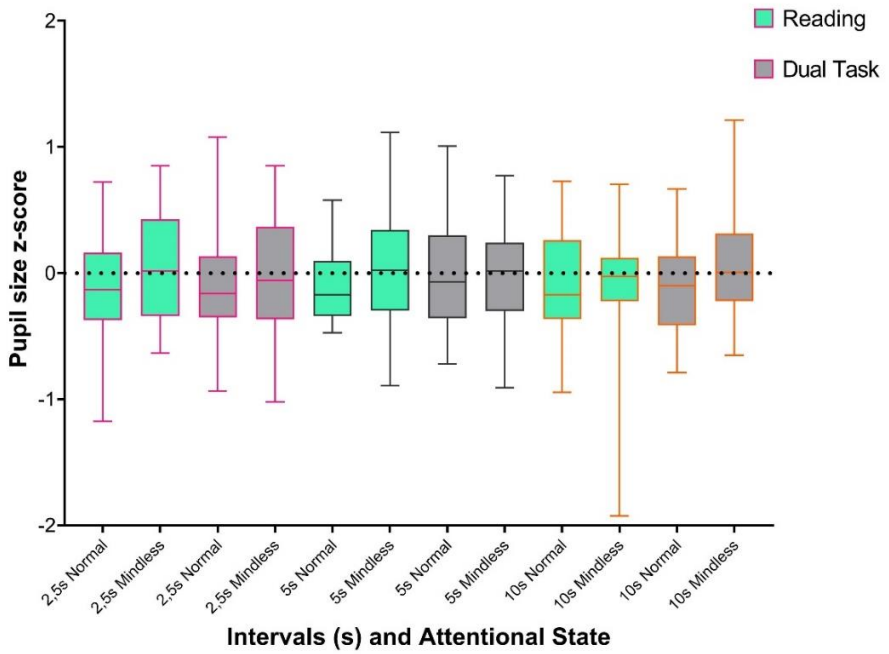
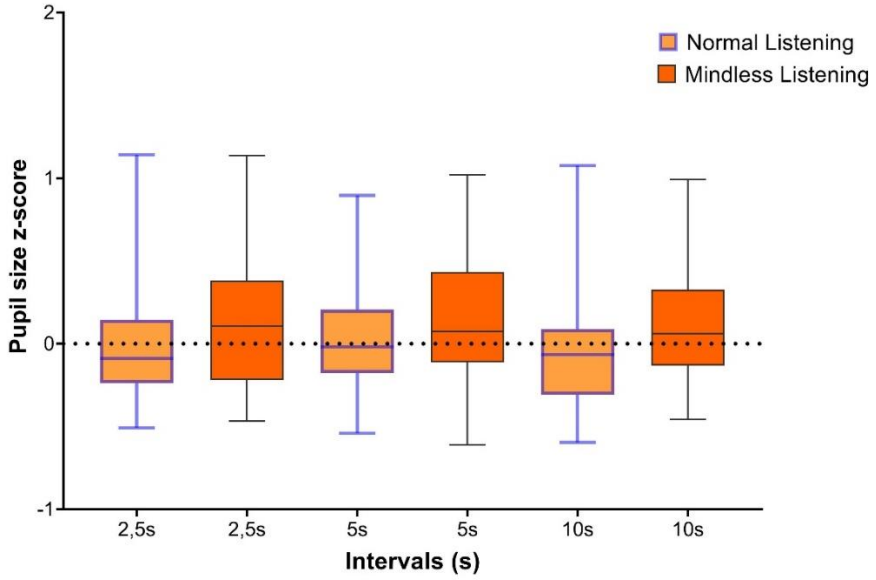


Figure 19 illustrates the mean pupil size in millimetres for the three intervals (2.5s, 5s and 10s), one stimulus (only listening) and two attentional states (mindless or normal). Post Hoc tests did not reveal any significant mean effects of attentional states or intervals on pupil size.

Figure 19

Mean pupil size measures during normal and mindless listening episodes as a function of interval length



4. DISCUSSION

The present study is, to the best of our knowledge, the first one which aimed to compare the effects of different modalities on mind wandering frequency and eye movements during mind wandering. In our study, we designed three independent conditions and examined and compared the frequency of mind wandering, the relation between comprehension and mind wandering, and the eye movements and pupil size during only during mind wandering. We observed significant differences in the number of fixations during mindless reading and mindless listening. Also, our statistically insignificant results replicated the results of previous studies on fixation duration and pupil size and contributed to the literature by addressing to actual inconsistencies.

4.1. Mind Wandering Frequency

In contrast to our expectations, mind wandering frequency was not associated with stimulus type. Our results filled an important gap in the literature, and revealed that participants' engagement in different tasks as reading, listening and simultaneously reading and listening did not characterize the frequency that participants reported off-task thoughts. All in all, modality does not affect the frequency of mind wandering episodes.

This finding yields important indications especially for dual task condition which consisted not only visual but also auditory cues. Previous studies suggested that the frequency of mind wandering increased in response to the decrease of the demands of the external world (Smallwood et al., 2008). On the contrary, Feng, D'Mello and Graesser (2013) found that difficult texts resulted in more mind

wandering episodes. Yet, in our study, during the dual task with increased cognitive and sematic load, the frequency of mind wandering episodes was no different than during other conditions consisting only one type of cue, that is, with lower cognitive load. So, our results show that even when the cognitive demands of the stimuli are very high, mind may wander frequently. The legitimate explanation of that relation between high cognitive load and frequent zone-outs may well result from the priority of inner thoughts. As Ho et al. (2020) suggested, the priority given to the "information that has greater personal relevance" draws attentional resources away from "the here and now" to inner thoughts robustly. Herewith, the changes in frequency of off-task thoughts can be attributed to the dominance and relevance of inner thoughts rather than the amount of cognitive load.

It is also important to highlight that our results are consistent with previous studies (Killingsworth and Gilbert, 2010) which indicate that mind wanders almost half of the time. During 20-minute-long experimental sessions, our participants' mean self-caught mind wandering frequency was 7.84 across all conditions. Although the duration of mind wandering episodes may vary greatly among individuals, it is important to highlight that the mean value of number of zone-outs in our study indicate that our participants caught themselves thinking about something other than the task in every 2 to 3 minutes.

Finally, the results of the experience-sampling tools showed that our participants' responses on how much some activities make them zone out were correct for reading and listening activities (see Figure 12). Although some mind wandering episodes sometimes may go unnoticed when they occur (Schooler et al., 2004), people generally have precise insights about when their attention usually tends to drawn away from the outer world. However, the same insights were not pronounced for dual

task condition. We believe that this is because people are inclined to think that when there is more information coming from the environment, they are more engaged in it.

4.2. Effects of Mind Wandering on Comprehension

In line with our hypothesis and previous work, mind wandering frequency had a negative effect on comprehension accuracy (see Figure 11). Participants who tended to zone-out more during tasks had less correct answers to the questions of the comprehension test. On the other hand, in addition to replicating the results of less comprehension during mindless reading (Sanchez and Naylor, 2018; Feng et al., 2013; Franklin et al., 2011, Smallwood et al.,2008), our study revealed that overall comprehension and performance quality are affected negatively by off-task thoughts not only during reading but also during listening and dual tasks. That there were no significant differences in mind wandering frequency among conditions (see Figure 10) proves that lower comprehension accuracy was not biased for any one of the modalities. Thus, our findings are especially important in that also during the dual task condition, which presented both visual and auditory cues of the same stimuli, mind wandering affected comprehension detrimentally.

4.3. Number of Fixations

As we expected, our findings on mind wandering episodes showed that there were more fixations in all intervals during reading task which had visual-lexical stimulus than during mindless listening which had auditory-lexical stimulus (see Figure 13). That is, there were significant differences in number of fixations during all intervals between mindless reading and mindless listening. As frequency of fixations in reading is associated with the effort put forth to comprehend the text (Uzzaman and

Joordens, 2011; Rayner and Fischer 1996), our findings show that eye movements display sensitivity to visual-lexical stimuli even in absence of conscious effort. Furthermore, the fact that number of fixations during dual task which consisted both visual- and auditory-lexical stimuli did not show any similar pattern to the other two and significant differences between mindless reading and mindless listening are absent in the comparison of mindless reading and mindless dual task indicates that there is an attentional decoupling mechanism in favour of visual-lexical stimulus during simultaneously-presented visual- and auditory-lexical stimulus.

Our analyses of fixation count during mindless and normal attentional states showed that there were no significant differences in number of fixations between mindless and normal attentional states in any of the intervals for any stimuli types. This finding is consistent with Uzzaman and Joordens' (2011) findings. These contrasts suggest that fixations are affected by visual lexical stimuli not only in attentive state but also in mindless state, and a low-level information processing for visual lexical stimuli continues even when the mind wanders and cognitive resources are drawn away from the task. All in all, our results indicate that "reading is more than a scene perception" (Rayner, 1998) not only in attentive state but also in mindless state.

Another remarkable finding of our study is that we observed more fixations during dual task than during the listening task in 2.5s-interval in attentive state (see Figure 14). As this interval refers to the time period immediately after self-caught zone-outs, we can conclude that after the moment of meta-awareness in dual task, participants showed more erratic eye movements. More erratic eye movements during dual task may be an indication of the urge of matching the auditory cure with the visual cue, that is, visual search.

4.4. Fixation Duration

Contrary to our hypothesis, analysis of fixation duration did not reveal any significant differences between conditions and intervals. Also, attentional states had no significant effect on fixation duration in line with our expectations and in consistency with previous studies (Uzzaman and Joordens, 2011; Smilek et al., 2010; Rayner and Fischer, 1996). As studies showed, longer fixation duration indicates more cognitive engagement and more time and effort for comprehension (Reichle et al., 2010). That is, increased length of fixations is associated with high-level processing of information. However, taking into consideration that the comprehension accuracy of the participants was affected negatively with the effect of mind wandering frequency across all conditions in our study, the fact that fixation duration did not differ for mindless and attentive states does not mean that high-level processing cue was present during mind wandering. But, particularly for mindless reading, it could suggest that automatic reading behaviour of eyes continues (Uzzaman and Joordens, 2011).

Our results also have some indications on the comparison of fixation duration during mindless reading and mindless listening. We observed more fixations during mindless reading than during mindless listening. But the total fixation lengths did not show any significant differences. These findings reveal that low-level processing of visual-lexical cues proceeds even when attention is decoupled from the text while the same pattern is not pronounced for listening. These results suggest, again, that eye movements display sensitivity to visual-lexical stimuli even in absence of conscious effort.

4.5. Pupil Size

Our assumption that pupil diameter would vary for mindless and normal states due to the effect of cognitive load was not confirmed. Our findings did not reflect any significant variations in pupil size between attentional states. That was consistent with the results of Uzzaman and Joordens's (2011) study which also implemented a naturalistic page-by-page reading task as ours. Also, there were no significant differences in pupil diameter within and between reading and dual tasks during both mind wandering and attentive states. This finding poses unexpected results in that decrease in pupil dilation due to less effort could have resulted in differences between attentional states during dual task which offered high cognitive load. As a whole, our findings might indicate that pupil diameter did not react to cognitive load and external stimuli as Smallwood et al. (2011) put it.

Yet, because of luminance inharmony, we did not compare the pupil size data of mind wandering epochs of visual-lexical cues and auditory-lexical cues. Thus, the differences in pupil size between mindless reading and mindless listening and between mindless dual task and mindless listening remain unclear.

4.6. Limitations

This study has several limitations. To begin with, the method we used to identify mind wandering episodes is the self-caught method. We did not prefer to use probe-caught method since it distracts participants and may affect both the duration and the frequency of mind wandering episodes. Although self-caught method is the most suitable method for our experimental design as we examine the frequency of mind wandering, it is only reliant on participant's capacity of meta-awareness. Thus,

for someone who has low capacity of realizing the occurrence of off-task thoughts, self-caught method may risk data collection.

Secondly, the results of pupil size analyses should not lead to a conclusion that there are not any significant effects of stimulus type on pupil size during mind wandering. These results do not indicate that the changes in pupil size are identical during mindless reading and mindless listening because we did not compare the changes in pupil size between mindless reading and mindless listening due to luminance disharmony between the stimuli. We should also underline that 60Hz sampling rate of our eye-tracker may be one limitation because it causes higher variability in the data (Franěk et al., 2018).

In addition, our study does not reveal information about the level of processing during mind wandering. The absence of significant differences in fixation count, fixation duration and pupil size between mind wandering and attentive states does not mean that high-level semantic processing is present during mind wandering. Previous studies showed that eye movements were less affected by linguistic variables such as word frequency during mindless reading episodes (Reichle et al., 2010). Thus, our results should be replicated with eye movement patterns such as regressions (backward saccades to an earlier position) and runs (two successive fixations in the area of interest), which provide more detailed information about the behaviour of eyes, to examine the effects of high-level linguistic variables such as ambiguity, word frequency and predictability.

4.7. Future Studies

Firsly, future studies could investigate the pupil size during mindless reading and mindless listening by taking the luminance effect into consideration. Secondly,

considering that human mind spends almost half of the waking life wandering, investigation of the periodicity of mind wandering episodes, if any, could be a research topic for future studies. Also, an fMRI- and machine learning-based neural decoding study, like the striking work of Horikawa and his colleagues (2013) on the contents of dreams, could be conducted to illuminate the contents during mind wandering episodes. Lastly, future studies could take a step further in light of Schad, Nuthmann and Engbert's study (2012) and reveal the behaviour of eyes during "weak" and "deep" levels of mind wandering.

4.8. Conclusion

In this study, we found that modality does not affect the frequency of mind wandering episodes, and the changes in frequency of spontaneous off-task thoughts can be attributed more to the dominance and relevance of inner thoughts compared to the demands of the immediate physical environment rather than the amount of cognitive load and stimulus type. Also, while fixation count, fixation duration and pupil size analyses did not yield any significant differences between mindless state and attentive state, number of fixations was significantly more during mindless reading than during mindless listening. Thus, our study shows that although the decrease in comprehension accuracy indicates that the processing of high-level semantic cues is affected negatively during mind wandering, the absence of any significant differences in fixation count and fixation duration between attentional states shows that a low-level processing of visual-lexical cues continues during mind wandering. These results indicate a sensitivity to visual-lexical stimulus even in absence of conscious effort and an attentional decoupling mechanism in favour of visual-lexical stimulus.

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APPENDIX A: Comprehension Test

Aşağıda, okuduğunuz, dinlediğiniz veya hem okuyup hem dinlediğiniz uyaranlara ilişkin 14 adet anlama sorusu yer almaktadır. Lütfen bunların her birini dikkatle okuyunuz. Daha sonra, doğru olduğunu düşündüğünüz seçeneği yuvarlak içine almak suretiyle işaretleyiniz.

1. Raskolnikov ev sahibesiyle karşılaşmaktan neden çekinmektedir?
    a. Ev sahibesine borçlu olduğu için
    b. Ev sahibesi ona annesini hatırlattığı için
    c. Ev sahibesini öldürmeyi planladığı için

2. Raskolnikov'un dış görünüşü nasıldır?
    a. Yakışıklı ve şık
    b. Çirkin ama bakımlı
    c. Yakışıklı ama bakımsız

3. Raskolnikov, tefecinin evine giderken ne hakkında düşünmektedir?
    a. Yeni görüşmeye başladığı kadın hakkında
    b. Mırıldanıp durduğu korkutucu planı hakkında
    c. Ev sahibesinden intikam almanın yolları hakkında

4. Raskolnikov, tefecinin evini terk ettiğinde nasıl hisseder?
    a. Kendinden tiksinmektedir.
    b. Yakalanmaktan korkmaktadır.
    c. Halinden memnun ama açtır.

5. Marmeladov'un mesleği nedir?
    a. Polis memuru
    b. Mahkeme memuru
    c. Devlet memuru

6. Sonya'nın ailesinden ayrı bir evde yaşamasının sebebi nedir?
    a. Katerina Ivanovna ile kavgaları
    b. Ev sahibinin izin vermemesi
    c. Evlenme isteği

7. Marmeladov'a göre Sonya artık neden paraya ihtiyaç duymaktadır?
    a. Temizliği için
    b. İçki için
    c. İtibarı için

8. Raskolnikov, Marmeladov'un evini terk etmeden önce ne yapar?
    a. Çocuklara sarılır.
    b. Aileye para bırakır.
    c. İzleyen insanlara bağırır.

9. Raskolnikov'a kimden mektup gelmiştir?
    a. Nastasya'dan
    b. Kız kardeşinden

c. Annesinden

10. Dunya, çalıştığı yerden neden kovulmuştur?
    a. Hırsızlık yaptığı için
    b. Ev sahibine aşkını ilan ettiği için
    c. Ev sahibi, Dunya'ya aşkını ilan ettiği için

11. Bu skandaldan sonra Dunya'ya itibarını geri kazandıran kanıt nedir?
    a. Dunya'nın ev sahibine yazdığı mektup
    b. Dunya'nın suçunu itiraf etmesi
    c. Dunya'nın halkı suçsuz olduğuna inandırması

12. Luzhin'in Dunya ile evlenmek istemesinin sebebi nedir?
    a. Dunya'nın elde edeceği miras
    b. Dunya'nın ona her zaman minnettar ve bağlı kalacak olması
    c. Dunya'nın zekasına duyduğu hayranlık

13. Dunya, Luzhin'in evlilik teklifini neden kabul etmiştir?
    a. Luzhin'e aşıktır
    b. Ünlü bir avukatın karısı olma hayali vardır
    c. Kardeşinin mesleki ve finansal çıkarını gözetmektedir

14. Raskolnikov, annesinin mektubunu okuduktan sonra ne yapmaya karar verir?
    a. Kardeşine iftira atan kişiyi öldürmeye
    b. Annesinin mektubunu göz ardı etmeye
    c. Kız kardeşinin evlilik planını bozmaya

APPENDIX B: Zoning-out Questionnaire

Aşağıda, kişilerin düşüncelere dalma deneyimlerini ve duygu durumlarını ifade etmede kullandıkları birtakım ifadelere yer verilmiştir. Lütfen her ifadeyi dikkatle okuyunuz. Bugün de dahil olmak üzere son bir aydır size en uygun olan cevabı yuvarlak içine almak suretiyle işaretleyin.

Her bir numara şu anlama gelmektedir:

0 = Asla / Hiç
1 = Çok az
2 = Orta derecede
3 = Oldukça fazla
4 = Aşırı / Hep

Gün içerisinde düşüncelere dalarım.	0	1	2	3	4
Bir şey okurken düşüncelere dalarım.	0	1	2	3	4
Bir şey dinlerken düşüncelere dalarım.	0	1	2	3	4
Bir şey izlerken düşüncelere dalarım.	0	1	2	3	4
Düşüncelere daldığımı hemen fark ederim.	0	1	2	3	4
Düşüncelere daldığımı fark etmem uzun zaman alır.	0	1	2	3	4
Çevremdeki değişiklikler düşüncelere daldığımı fark etmemi sağlar.	0	1	2	3	4
Stresliyken daha çok düşüncelere dalarım.	0	1	2	3	4
Rahatken daha çok düşüncelere dalarım.	0	1	2	3	4
Bir işle uğraştığımda daha çok düşüncelere dalarım.	0	1	2	3	4
Bir işle uğraşmadığımda daha çok düşüncelere dalarım.	0	1	2	3	4
Daldığım düşünceler uğraştığım şey ile alakalıdır.	0	1	2	3	4
Daldığım düşünceler gelecekle alakalıdır.	0	1	2	3	4
Daldığım düşünceler geçmişle alakalıdır.	0	1	2	3	4
Daldığım düşünceler hayatımdaki insanlarla alakalıdır.	0	1	2	3	4
Daldığım düşünceler görüntüler şeklindedir.	0	1	2	3	4
Daldığım düşünceler kelimeler şeklindedir.	0	1	2	3	4
Hayatımın bu döneminde stresli hissediyorum.	0	1	2	3	4
Hayatımın bu döneminde çok yoğunum.	0	1	2	3	4
Hayatımın bu döneminde yalnız hissediyorum.	0	1	2	3	4
Hayatımın bu döneminde daha çok düşüncelere dalıyorum.	0	1	2	3	4

APPENDIX C: Results of Zoning-out Questionnaire