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LITERATURAS, CULTURAS Y SUS APLICACIONES

An eye tracking study of the role of Advanced L2 learners' attention in phrasal verbs processing

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ABSTRACT

This study investigated how phrasal-verb primes shape both behavioural performance and eye-movement behaviour during the processing of subsequent target verbs in a second language (L2). Building on research in priming, multi-word expressions, and L2 vocabulary learning, the study examined (a) how different prime–target relationships (related, unrelated, neutral, pseudoword, filler) affect fixation-based eyemovement metrics, (b) how these metrics relate to reaction time, and (c) how prime type influences overall task performance in terms of speed and accuracy, as an index of attention allocation and implicit versus explicit processing. Participants were 30 Persian L1 upper-intermediate English learners. They completed a lexical decision task (LDT) in which target verbs were preceded by briefly presented phrasal-verb primes (e.g., figure out / figure). The experiment lasted 20 minutes and included 300 trials, 60 of which contained related prime-target pairs. Participants' eye movements were recorded using an SMI eye tracker. Eye movements were recorded for first fixation duration, fixation count, total fixation duration, and glance duration, alongside reaction time and accuracy. Repeated-measures ANOVAs and correlation analyses were used to compare prime–target conditions and to explore the links between eye-movement behaviour and decision speed. The results showed robust effects of prime–target condition on both fixation patterns and behavioural performance. Related and neutral primes typically led to relatively longer first fixations but shorter total fixation durations and faster reaction times, indicating an initial attentional cost followed by facilitation once semantic or associative coherence was established. In contrast, pseudoword and filler conditions elicited longer total fixations, more fixations, slower responses, and, in the case of fillers, lower accuracy, revealing increased cognitive load when no meaningful support was available. Saccade measures did not differ significantly across conditions, suggesting that priming effects were mainly reflected in fixation behaviour rather than in global eye-movement dynamics. Correlations between fixation metrics and reaction time were modest and condition-dependent, but they showed that, in certain conditions, differences in fixation patterns were systematically associated with differences in processing speed. Overall, the findings demonstrate that phrasal-verb primes can exert measurable effects on where, for how long, and how efficiently L2 readers process subsequent target verbs. The study highlights eye-movement behaviour as a sensitive indicator of attention allocation during L2 lexical processing and shows that even brief

exposure to phrasal-verb primes can influence both online processing and overt task performance. By combining eye-tracking and behavioural data, this research offers a detailed account of implicit and explicit processes in L2 phrasal-verb processing and points to important implications for the teaching and learning of phrasal verbs in instructional contexts.

RESUMEN

Este estudio investigó cómo los priming de verbos compuestos influyen tanto en el rendimiento conductual como en el comportamiento de los movimientos oculares durante el procesamiento de verbos objetivo posteriores en una segunda lengua (L2). Basándose en investigaciones sobre priming, expresiones de varias palabras y aprendizaje de vocabulario en L2, el estudio examinó (a) cómo las diferentes relaciones entre priming y objetivo (relacionadas, no relacionadas, neutras, pseudopalabras, relleno) afectan a las métricas de movimiento ocular basadas en la fijación, (b) cómo estas métricas se relacionan con el tiempo de reacción, y (c) cómo el tipo de priming influye en el rendimiento general de la tarea en términos de velocidad y precisión, como índice de la asignación de atención y del procesamiento implícito frente al explícito. Los participantes fueron 30 estudiantes de inglés de nivel intermedio-alto con el persa como L1. Completaron una tarea de decisión léxica (LDT) en la que los verbos objetivo iban precedidos de priming de verbos compuestos presentados brevemente (por ejemplo, figure out / figure). El experimento duró 20 minutos e incluyó 300 ensayos, 60 de los cuales contenían pares de priming-objetivo relacionados. Los movimientos oculares de los participantes se registraron utilizando un rastreador ocular SMI. Se registraron los movimientos oculares para determinar la duración de la primera fijación, el número de fijaciones, la duración total de las fijaciones y la duración de las miradas, junto con el tiempo de reacción y la precisión.

Se utilizaron ANOVA de medidas repetidas y análisis de correlación para comparar las condiciones de priming-objetivo y explorar los vínculos entre el comportamiento de los movimientos oculares y la velocidad de decisión. Los resultados mostraron efectos sólidos de la condición de priming-objetivo tanto en los patrones de fijación como en el rendimiento conductual. Las primas relacionadas y neutras suelen dar lugar a fijaciones iniciales relativamente más largas, pero con una duración total más corta y tiempos de reacción más rápidos, lo que indica un coste atencional inicial seguido de una facilitación una vez establecida la coherencia semántica o asociativa. Por el contrario, las condiciones de pseudopalabras y relleno provocaron fijaciones totales más largas, más fijaciones, respuestas más lentas y, en el caso de los rellenos, una menor precisión, lo que reveló una mayor carga cognitiva cuando no se disponía de un apoyo significativo. Las medidas de sacádicos no difirieron significativamente entre las

condiciones, lo que sugiere que los efectos de priming se reflejaron principalmente en el comportamiento de fijación y no en la dinámica global del movimiento ocular. Las correlaciones entre las métricas de fijación y el tiempo de reacción fueron modestas y dependientes de la condición, pero mostraron que, en ciertas condiciones, las diferencias en los patrones de fijación se asociaban sistemáticamente con diferencias en la velocidad de procesamiento. En general, los resultados demuestran que los priming de verbos frasales pueden ejercer efectos medibles sobre dónde, durante cuánto tiempo y con qué eficiencia los lectores de L2 procesan los verbos objetivo posteriores. El estudio destaca el comportamiento del movimiento ocular como un indicador sensible de la distribución de la atención durante el procesamiento léxico de la L2 y muestra que incluso una breve exposición a los priming de verbos compuestos puede influir tanto en el procesamiento en línea como en el rendimiento manifiesto de la tarea. Al combinar datos de seguimiento ocular y de comportamiento, esta investigación ofrece una descripción detallada de los procesos implícitos y explícitos en el procesamiento de verbos compuestos en una segunda lengua y señala importantes implicaciones para la enseñanza y el aprendizaje de verbos compuestos en contextos educativos.

RESUM

Aquest estudi va investigar com la priming de verbs compostos influeix tant en el rendiment conductual com en el comportament dels moviments oculars durant el processament de verbs objectiu posteriors en una segona llengua (L2). Basant-se en la recerca sobre el priming, les expressions pluriparaulals i l'aprenentatge de vocabulari en una segona llengua (L2), l'estudi va examinar (a) com diferents relacions entre el prim i l'objectiu (relacionades, no relacionades, neutres, pseudoparaules, de farciment) afecten les mètriques de moviments oculars basades en la fixació, (b) com aquestes mètriques es relacionen amb el temps de reacció, i (c) com el tipus de priming influeix en el rendiment global de la tasca en termes de velocitat i precisió, com a índex de l'assignació de l'atenció i del processament implícit enfront del explícit. Els participants van ser 30 aprenents de nivell superior intermedi d'anglès, amb el persa com a primera llengua. Van completar una tasca de decisió lèxica (LDT) en la qual els verbs objectiu anaven precedits d'un priming de verbs compostos presentat breument (per exemple, figure out/figure). L'experiment va durar 20 minuts i va incloure 300 proves, 60 de les quals contenien parells d'estímul-blí relacionats. Els moviments oculars dels participants es van enregistrar amb un seguidor ocular SMI. Es van enregistrar els moviments oculars per determinar la durada de la primera fixació, el nombre de fixacions, la durada total de les fixacions i la durada de les mirades, juntament amb el temps de reacció i la precisió. Es va utilitzar una ANOVA de mesures repetides i una anàlisi de correlació per comparar les condicions de priming del blanc i explorar els vincles entre el comportament dels moviments oculars i la velocitat de presa de decisions. Els resultats van mostrar efectes forts de la condició de priming de l'objectiu tant en els patrons de fixació com en el rendiment conductual. Els estímuls de priming relacionats i neutres normalment van donar lloc a fixacions inicials relativament més llargues, però amb una durada total més curta i temps de reacció més ràpids, la qual cosa indica un cost atencional inicial seguit d'una facilitació un cop s'estableix la coherència semàntica o associativa. En canvi, les condicions de pseudoparaules i de coneguts de farciment van resultar en fixacions totals més llargues, més fixacions, respostes més lentes i, en el cas dels coneguts de farciment, una precisió més baixa, la qual cosa revela una càrrega cognitiva més gran quan no hi havia cap suport semàntic disponible. Les mesures sacàdiques no van diferir significativament entre condicions, cosa que suggereix que els efectes de priming es van reflectir principalment en el comportament de fixació més que no pas en la dinàmica global dels moviments oculars.

Les correlacions entre les mètriques de fixació i el temps de reacció van ser modestes i depenien de la condició, però van mostrar que, en certes condicions, les diferències en els patrons de fixació estaven sistemàticament associades a diferències en la velocitat de processament. En general, els resultats demostren que el condicionament de verbs frasals pot exercir efectes mesurables sobre on, durant quant de temps i amb quina eficiència els lectors de L2 processen els verbs objectiu posteriors. L'estudi destaca el comportament dels moviments oculars com a indicador sensible de la distribució de l'atenció durant el processament lèxic en L2 i mostra que fins i tot una exposició breu a l'activació de verbs compostos pot influir tant en el processament en línia com en el rendiment explícit de la tasca. En combinar el seguiment ocular i les dades de comportament, aquesta recerca proporciona una descripció detallada dels processos implícits i explícits implicats en el processament de verbs compostos en una segona llengua i assenyala implicacions importants per a l'ensenyament i l'aprenentatge de verbs compostos en contextos educatius.

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Chapter 1. Introduction

Second language acquisition and its related areas have long been appealing topics of discussion, particularly among language teachers, linguists, and psycholinguists. The question of whether a language is learned implicitly or explicitly has attracted considerable attention from researchers. For some scholars, language learning largely equates to vocabulary acquisition, as vocabulary plays a crucial role in the process of acquiring a language. Vocabulary can be learned while learners are doing some other tasks implicitly, or they can be learned while learners are conscious of learning them. Notably, the role of attention in language learning has been underscored by numerous researchers (e.g., Robinson, 1996, 2003, 2008; Schmidt, 1995, 2010). It is widely acknowledged that effective learning transpires when attention is directed towards specific words or phrases in the language learning process.

Phrasal verbs, as a crucial component of vocabulary, play a significant role. Given that many learners encounter difficulties in mastering them, it is worthwhile to reconsider how they are approached. Learning vocabulary is an essential task on the language acquisition journey, contributing to proficiency in English, albeit a challenging aspect to navigate. Phrasal verbs, with their inherent dynamism, contribute significantly to the expressiveness and flexibility of language. They embody the subtleties of idiomatic usage, enabling learners not only to communicate effectively but also to convey nuanced meanings that transcend literal interpretations.

In the realm of phrasal verbs, the role of attention takes center stage in the intricate process of reading and learning. As readers encounter these linguistic constructs, attentional mechanisms guide the allocation of cognitive resources, influencing comprehension and lexical decision-making. The conscious focus on phrasal verbs enables explicit learning, whereas implicit learning may occur as attention is subtly directed during broader language tasks. Research suggests that the depth of attention, as emphasized by psycholinguistic studies (e.g., Robinson, 2008; Schmidt, 1995), correlates with successful language acquisition, prompting an exploration of how attention operates in the specific context of phrasal verb processing.

Moreover, advancements in technology have opened new avenues for studying language acquisition processes, including the use of eye tracking methodology. Eye tracking studies have provided valuable insights into how learners allocate attention during language processing tasks, shedding light on the cognitive mechanisms underlying vocabulary acquisition and phrasal verb comprehension. For example, research by Pellicer-Sánchez and Siyanova-Chanturia (2018) demonstrated that eye movements can serve as an indicator of lexical access and processing efficiency, with longer fixation durations observed for unfamiliar phrasal verbs compared to familiar ones. Also, other studies depicted the same result (e.g., Pellicer-Sánchez and Pérez, 2024).

Building upon these insights, the present study employs eye tracking methodology to investigate the role of attention in phrasal verb processing. By tracking participants' eye movements as they engage with phrasal verbs in context, we aim to elucidate the attentional mechanisms involved in lexical access and comprehension. Specifically, we hypothesize that attentional allocation will vary depending on factors such as verb familiarity, particle salience, and contextual richness, ultimately influencing learners' ability to comprehend and retain phrasal verb meanings. Through the integration of eye tracking technology into our experimental design, we seek to enhance the ecological validity of our findings and provide a more nuanced understanding of phrasal verb processing.

By examining the dynamics of attention during language processing tasks, our study contributes to the growing body of research on vocabulary acquisition and language learning, offering practical implications for educators and researchers alike. Additionally, our findings may inform the development of instructional strategies and interventions aimed at improving phrasal verb comprehension and facilitating language acquisition in educational settings. The intentional focus on phrasal verbs facilitates explicit learning, enabling deliberate cognitive processing, while implicit learning unfolds as attention subtly guides comprehension during broader language tasks. This study stands as a natural extension of the established groundwork in psycholinguistics, delving into the multifaceted interplay between attention and the comprehension of phrasal verbs.

Drawing on the rich tapestry of language acquisition research, this investigation seeks to provide a more comprehensive understanding of the cognitive dynamics involved in the acquisition and comprehension of phrasal verbs. As we delve into this exploration, our intent is to offer valuable insights for educators, linguists, and researchers seeking to enhance language acquisition methodologies and further the collective knowledge in the field.

1.1. Statement of the Problem

Multi words are a matter of interest in learning second language vocabulary. As different debates go, multi words are stored in one lexical part of the mind or different parts. One category of multi words are phrasal verbs, which may be considered a difficult part for students to learn (Alangari, Jaworska, & Laws, 2020). Some studies (e.g., Liao & Fukuya, 2004; Saiya, 2011; El-Dakhs, 2016; Minalla, 2024) have shown that English language learners prefer not to use phrasal verbs and would rather use one-word synonyms whenever it is possible. Learning phrasal verbs is such a challenge to language learners (Cowie, 1993) due to their idiomatic nature, varying meanings based on context, and the difficulty in predicting their semantic relationships between the verb and particle.

Many teachers and students testify that term phrasal verbs are not liked by students (Dagut & Laufer, 1985; Alhassani, 2023; Talib & Ashraf, 2024), and language learners try to avoid them (Laufer & Eliasson, 1993; Liao & Fukuya, 2004; Okuwaki, 2021; Alwreikat & Yunus, 2022). Phrasal verbs are syntactically peculiar and semantically complicated and these features contribute to an unnatural structure for some learners, especially those who do not have phrasal verb construction in their native language. Phrasal verbs are composed of at least two components, which leads some learners to not know them as a single semantic unit and try to decode each component separately and misinterpret them. Phrasal verbs are a great significant feature of language, and they happen 2,000 times every million words (Biber et al., 1999). Similarly, as David and Gardner (2007) claimed, learners face one phrasal verb per 150 English words. Therefore, learning phrasal verbs is essential to learning the English language. Since phrasal verbs are common in everyday speaking and informal situations, if learners put

them aside because of their complex construction, they would sound non-native and unnatural (Siyanova & Schmitt, 2007). One can observe two sentences: I get up at 7 o'clock in comparison with I arise at 7 o'clock, to see which one sounds authentic.

Having reviewed the related literature, many debates have been formed around phrasal verbs, their difficulty in learning, phrasal verb avoidance, and whether they are a single lexical unit or not. The significance of learning phrasal verbs is approved among language teaching communities, and the number of dictionaries (e.g., Longman Phrasal Verbs Dictionary, Oxford Phrasal Verbs Dictionary, Cambridge Phrasal Verbs Dictionary, MacMillan Phrasal Verbs Plus Dictionary) and books, which are dedicated to phrasal verbs acknowledge its importance.

Learning phrasal verbs is both important and challenging for language learners. Despite their importance, however, they have often been overlooked in research. Consequently, greater attention should be given to phrasal verbs and the way they are processed in order to address this gap. Although learning phrasal verbs poses a significant challenge for language learners, it remains a relatively underexplored area of study. To address this gap, our research delves into the processing of phrasal verbs, leveraging eye tracking technology to gain insights into learners' attentional patterns. By examining which aspects of phrasal verbs garner more attention from learners, such as the verb or the particle, we aim to elucidate the cognitive processes underlying phrasal verb comprehension. For instance, do learners rely on their knowledge of the base verb to decipher phrasal verbs like "get off," or do they focus more on the particle? Additionally, understanding how advanced non-native learners encounter phrasal verbs can shed light on the complexities of learning in this domain. Through our utilization of eye tracking technology, we seek to uncover novel findings that contribute to a deeper understanding of phrasal verb processing and inform more effective language instruction practices.

1.2. Research Hypotheses

In light of the above, the present study addresses the following research questions:

1. Hypothesis 01: There is no significant difference in fixation metrics (first fixation duration, fixation count, and total fixation duration) across different primetarget relationships (related, unrelated, pseudoword, neutral, filler).
2. Hypothesis 02: There is no significant relationship between fixation metrics and reaction time during the lexical decision task for phrasal verbs.
3. Hypothesis 03: There is no significant difference in task performance (reaction time and accuracy) across different prime-target conditions, and no evidence that these conditions influence the type of cognitive processing (implicit vs. explicit).

1.3. Objectives

The general objective identified in this thesis is to investigate the role of attention in the processing of phrasal verbs among advanced English speakers using eye-tracking technology within a Lexical Decision Task (LDT) framework.

From this, the specific objectives are the following:

1. To examine the influence of prime-target relationships (related, unrelated, pseudo, neutral, fillers) on fixation metrics during the processing of phrasal verbs.
2. To explore the relationship between fixation metrics and reaction time in the processing of phrasal verbs.
3. To evaluate how prime-target conditions affect task performance (reaction time and accuracy) and reveal patterns of implicit vs. explicit processing during phrasal verb recognition.

1.4. Research Questions

From these objectives, some research questions were posed:

1. How do different prime-target relationships (related, unrelated, pseudo, neutral, fillers) influence fixation metrics (first fixation duration, fixation count, total

fixation duration) during the processing of phrasal verbs?

2. What is the relationship between fixation behaviors (e.g., fixation duration, fixation count) and reaction times during the lexical decision task for phrasal verbs?
3. How do prime-target conditions affect task performance (reaction time and accuracy), and what do these patterns reveal about implicit versus explicit processing mechanisms?

1.5. Significance of the study

This study holds significant implications across various dimensions of language research and pedagogy. Firstly, it addresses a cognitive gap in our understanding of phrasal verb processing. As noted by White (2012), the inherent complexity of phrasal verbs poses challenges for comprehension. By examining the role of attention in processing these linguistic structures, the study contributes valuable insights into the allocation of cognitive resources and potential strategies for overcoming processing difficulties.

Many learners struggle with the complexity of phrasal verbs, as they often resist simple translation and require contextual comprehension. Thus, rethinking teaching methods becomes crucial to clarify these linguistic elements and encourage a more natural learning process. Phrasal verbs, with their dynamic nature, greatly enhance the depth and adaptability of language expression. They capture the nuances of idiomatic usage, allowing learners to convey nuanced meanings beyond literal interpretations.

In the realm of language learning, mastering phrasal verbs plays a crucial role. English, rich in phrasal constructions, requires a strong grasp of these linguistic elements for proficiency. Understanding phrasal verbs equips learners with essential communication skills for various contexts, formal and informal alike. Therefore, a strategic approach to learning phrasal verbs not only tackles a specific linguistic hurdle but also significantly enhances overall language proficiency. Essentially, achieving linguistic excellence in English hinges on a thorough command of phrasal verbs (Thao and Bon 2023).

In the domain of language teaching, this research offers valuable insights into instructional methods, especially for educators assisting learners in understanding the complexities of phrasal verbs. Webb and Nation (2017) highlight the crucial importance of vocabulary in language learning, and the findings of this study can assist instructors in developing teaching strategies that promote both explicit and implicit learning. This has the potential to enhance the efficacy of language education, particularly in areas where learners struggle with phrasal verbs.

From a psycholinguistic perspective, the study advances our understanding of attentional mechanisms in language processing, particularly concerning phrasal verb comprehension. One significant determinant affecting whether input transitions into intake is the level of attention directed towards it (Doughty, 2001; Robinson et al., 2012; Schmidt, 1990, 2010).

The findings contribute valuable insights to psycholinguistic theories, elucidating the cognitive processes underlying the comprehension of complex linguistic structures. Not only becoming aware of how phrasal verbs are being processed is important but also the way they draw the attention is worth considering, whether their first part which is verb draws the attention more or whether particles draws the attention, it is out of question if the particles do not draw much attention would be a root of students problem recalling the meaning of specific phrasal verbs, it could be mixed up, whether the verb was combined with “in, on, out, off”; for instance, get off, get in, get out, get up. Or, as some scholars believe, they are being learned as a whole unit, which is elaborated more in the literature review.

Furthermore, this study not only impacts theories of language acquisition, particularly those examining implicit and explicit learning (Ellis, 2005; Ellis and Roever, 2021) but also offers practical applications in fields such as language technology and cognitive science. Understanding how attention operates in processing phrasal verbs can lead to the development of language technologies that aid learners in overcoming challenges associated with these structures. Additionally, insights from this research may inform the design of cognitive interventions for individuals struggling with phrasal verb comprehension due to attentional constraints.

This study employed advanced eye movement recording techniques to capture participants' gaze patterns as they underwent the experimental task of reading phrasal verbs presented on a computer screen. By analyzing these eye movements, we aimed to gain a deeper understanding of how attention operates during the processing of phrasal verbs. The use of eye tracking technology allowed for precise measurements of participants' visual attention, providing valuable data on which aspects of phrasal verbs attracted more attention and how attentional resources were allocated during comprehension. This innovative approach enhances the rigor and depth of our investigation into the cognitive processes underlying phrasal verb processing. Additionally, integrating eye tracking methodology into the experimental design strengthens the validity and reliability of our findings, offering robust evidence to support our conclusions regarding the role of attention in comprehending phrasal verbs.

In summary, this research goes beyond just understanding phrasal verbs, offering valuable insights into language instruction, psycholinguistics, language acquisition theories, crosslinguistic comparisons, and practical applications. Enhancing our understanding of how attention works in language processing paves the way for deeper exploration in these diverse fields.

1.6. Structure of the thesis

This thesis is organized into five chapters, each addressing key aspects of the research and contributing to a comprehensive understanding of the role of attention in processing phrasal verbs among advanced English speakers using eye-tracking technology.

In Chapter 1, the study's background, research questions, and objectives, as well as the significance of the study, are introduced, establishing the central focus on the role of attention in processing phrasal verbs among advanced English speakers using eye tracking technology. This foundation sets the stage for the comprehensive review of literature presented in Chapter 2.

In Chapter 2, we explore various critical aspects necessary to understand the processing of phrasal verbs among advanced English speakers, with a particular focus on attention and eye-tracking technology. The review covered the following key areas:

- **The Nature and Complexity of Phrasal Verbs:** The chapter addresses the multifaceted nature of phrasal verbs, distinguishing between literal, aspectual, or semi-transparent, and idiomatic or figurative meanings. It also highlights challenges learners face, such as avoidance and frequency issues, emphasizing cognitive linguistics-inspired methods for teaching and learning these verbs.
- **Vocabulary Acquisition in L2 Learning:** Insights into second language vocabulary acquisition are discussed, comparing implicit and explicit learning and the roles of L1 and L2 incidental learning. Factors influencing vocabulary acquisition are also examined to provide a broader context for understanding how learners process and retain complex structures like phrasal verbs.
- **The Role of Attention in Language Learning:** The chapter details the critical role of attention in language learning, particularly in relation to awareness, word learning, and measuring attention. The relationship between attention and learning strategies in second language acquisition (SLA) is emphasized, forming a theoretical foundation for analysing eye-tracking data.
- **Semantic Priming and Its Impact:** A thorough discussion of semantic priming provides insight into its application in L2 learning. Different types of priming and methods, including the use of EEG and fMRI, are reviewed to understand how priming influences word and phrasal verb learning. The connection between semantic priming and attention allocation is highlighted, demonstrating its relevance to this study's experimental design.
- **Eye-Tracking Methodology:** Finally, the chapter introduces eye-tracking as a powerful tool for investigating real-time language processing. Applications of eye tracking in second language learning, reading, and vocabulary research are explored.

Chapter 3 outlines the research design and methodological approach. It describes the participants (30 advanced English speakers) and their selection criteria, ensuring a homogenous sample for reliable data interpretation. The experimental design is explained in detail, focusing on the Lexical Decision Task (LDT) with 300 prime-target pairs categorized into five conditions: related, unrelated, pseudo, neutral, and fillers. Each trial sequence is broken down, highlighting the timeline (fixation mark, masked

priming, prime display, target display, and response page). This chapter also explains the use of eye-tracking technology, detailing the metrics collected (first fixation duration, fixation count, and total fixation duration) and their relevance to the study's objectives. Finally, the chapter discusses the data analysis procedures, including the statistical methods used to assess fixation metrics, reaction times, and accuracy.

Chapter 4 presents the findings of the study, organized around the specific research questions and hypotheses. The results are divided into sections corresponding to each objective:

- Prime-target relationships: Analysis of fixation metrics across related, unrelated, pseudo, neutral, and filler conditions.
- Fixation and reaction time correlations: Examination of how fixation behaviors (e.g., fixation duration, fixation count) relate to reaction times, highlighting cognitive processing patterns.
- Response time comparisons: Comparison of response times across different prime-target conditions, identifying semantic priming effects.
- Implicit vs. explicit processing: Evaluation of task performance (accuracy and reaction time) and fixation data to distinguish between implicit and explicit attention strategies.

Chapter 5, conclusions, synthesizes the findings, relating them to the research hypotheses and the broader literature. It discusses the implications for language learning and teaching, particularly in the context of phrasal verbs, and offers pedagogical recommendations based on the insights gained from the study. The chapter concludes with limitations of the research and suggestions for future studies.

Chapter 2. Theoretical Background

This chapter reviews the theoretical and empirical literature relevant to the present study on second language learners' acquisition of English phrasal verbs, with particular attention to priming and eye-tracking methodologies. Section 2.1 introduces multi-word verbs and focuses in detail on phrasal verbs, examining their nature, distinguishing them from prepositional verbs, outlining their semantic types (literal, aspectual, and idiomatic), and considering the difficulties learners face, their tendency to avoid them, and frequency-based as well as cognitively oriented approaches to their teaching and learning. Section 2.2 then turns to vocabulary learning in second language acquisition, presenting key perspectives on L2 vocabulary acquisition, ways vocabulary can be learned, the role of implicit and explicit learning, the relationship between L1 and L2 incidental learning, and factors influencing vocabulary development. Section 2.3 discusses the construct of attention and its role in SLA. Section 2.4 surveys the literature on priming, defining the concept, outlining main priming types and methods, and highlighting their use in L2 learning and phrasal verb research. Finally, Section 2.5 introduces eye-tracking as an online methodology in language processing, detailing relevant eye-movement measures and summarizing studies that have used eye-tracking in second language learning, reading, vocabulary research, and priming.

2.1. Multi-word verbs

Multi-word items can be considered as fixed collocation cases. Any strings of vocabulary that are more than one word are named multi-word items (Moon, 1997). This series of words shapes a semantically and, sometimes, syntactically meaningful and integral unit. In shaping multi-words, lexical and semantic processes play a more significant role than syntactic rules. Moon (1997) categorized three features to characterize multi-words:

- Institutionalization (i.e., how common it is among language users), fixedness (i.e., the degree of being frozen as an item).
- Noun-compositionality (i.e., the degree of word-by-word interpretation).
- “Formulaic language” in the related literature is an umbrella term for all phenomena in language, such as collocations, chunks, prefabricated routines, formulaic speech, and multi-word units, ready-made utterances (Wray, 2002).

Therefore, multi-word units are a type of formulaic language. To be aware of how significant the role of learning formulaic language is when one is learning a new language, it is good enough to refer to an approximate number of ‘prefabs’ for 58.6 percent of spoken English and 52.3 percent of written English (Erman & Warren 2000). According to Biber et al. (1999), phrasal verbs occur nearly 2,000 times per million words in stories and conversations. Regarding the fact that they excluded literal phrasal verbs and categorized them as free combination, the number of phrasal verbs is much larger than what they have claimed (Liu, 2011). Following up on Biber et al.’s research, Gardner and Davis (2007) carried out a corpus-based study on phrasal verbs, aiming to validate the list of most frequent phrasal verbs declared in Longman Dictionary. They conclude that language learners will encounter approximately one PV in every one hundred and fifty (150) words in English.

2.1.1 The Nature of Phrasal Verbs

Phrasal verbs (PVs) are commonly classified as one type of multi-word unit. They have attracted sustained scholarly attention (e.g., Fraser, 1974; Cornell, 1985; Side, 1990; Darwin & Gray, 1999; Liao & Fukuya, 2004; Gardner & Davies, 2007; Siyanova & Schmitt, 2007). Early work, such as Fraser (1974) and Cornell (1985), helped to describe and classify PVs, while more recent corpus-based studies, notably Gardner and Davies (2007) and Siyanova and Schmitt (2007), have documented their frequency and patterns of use in contemporary English. Liao and Fukuya (2004) are particularly influential in linking phrasal verb usage to L2 learners’ avoidance behaviour. In addition, a number of studies have focused explicitly on the difficulty of learning PVs for language learners (e.g., Walková, 2012; Al Nasarat, 2018; Hlaing, 2021), consistently reporting that PVs pose a persistent challenge in both comprehension and production.

A variety of terms have been used for phrasal verbs in the literature, such as “verb–adverb combination” (Kennedy, 1920, as cited in Kosolsombat & Pongpairaj, 2017), “two-word verb” (e.g., Taha, 1960; Siyanova & Schmitt, 2007), and “verb–particle combination” (Fraser, 1974). In this study, the term phrasal verb is used, as it is the most common one in different studies (e.g., Darwin & Gray, 1999; Liao & Fukuya, 2004;

Gardner & Davies, 2007). Besides, this term appears in textbooks and dictionaries more frequently than other terms used to describe this type of multi-word structure. Phrasal verbs (PVs) are described as a set of words that is used like a verb and consists of a verb with an adverb or preposition after it (Longman, 2014). For instance, the second part can be an adverbial particle (e.g., up, down, out) as in get up, sit down, give out, or it consists of a preposition (e.g., after, into, with) as in take after, run into, cope with. It is somewhat difficult to distinguish between phrasal verbs and prepositional verbs (look out vs. look at) for learners, and dictionaries add confusion by long lists of phrasal verbs (Liu, 2011). The same systematic division of multi-word verb has been proposed by Lindstromberg (2010) mentioning three categories 1) Prepositional verbs: e.g., look for a job in which for refers to somebody 2) True phrasal verbs: e.g., look up a new word in a dictionary in which up is a particle 3) Phrasal prepositional verbs: e.g., get along with a person in which a phrasal verb get along is followed by a preposition.

The most precise definition for a phrasal verb may refer to Darwin and Gray (1999), who stated that a phrasal verb includes two parts of a verb and a morphologically inflexible particle that functions as a single unit. The feature that is fairly helpful to distinguish between authentic phrasal verbs and prepositional verbs is the idea that phrasal verbs function as a single grammatical and lexical unit. In the latter one, the verb and the preposition have individual meaning, and they are separated, for instance, in the sentence he looked at his car; at is an independent part of the verb. Therefore, it is called a prepositional phrase. However, phrasal verbs function as a single lexical unit, and most of them can be substituted by a one-word equivalent. Also, their meaning is both different from the verb without a particle (e.g., turn off is not the same as turn) and dissimilar to the same verb with various particles, for example, turn off and turn on.

2.1.2. Different Categories of Phrasal Verbs

There are different categories of phrasal verbs, one of which is made by Celce-Murcia and Larsen-Freeman (1999) that illustrates three semantic classifications of phrasal verbs: literal, idiomatic, and aspectual. Literal phrasal verbs are those that have a similar meaning to the meaning of the individual parts (e.g., look and up in When he heard the crash, he looked up). Idiomatic phrasal verbs consist of a verb and a particle that, when

combined, have a totally different meaning from their individual parts (e.g., give and up in the sentence I gave up smoking. They have the new meaning of quit, which is not related to the meaning of give or up). Aspectual phrasal verbs fall somewhere between the continuum of literal and idiomatic phrasal verbs. Their meanings are not as obvious as the literal meaning but more transparent than meanings in idiomatic phrasal verbs (e.g., up in fill up means entirely, and fill maintains its original meaning as in fill up the tank).

It is worth mentioning that some scholars, such as Darwin and Gray (1999) and Biber et al. (1999), considered literal verb plus particle, like go in, come down, as free combinations; they claimed their meanings are close to their individual parts and are predictable. Some others categorized them as literal phrasal verbs (e.g., Gardner and Davies (2007) and Liu (2011)). From a grammatical point of view, phrasal verbs are divided into two categories: transitive and intransitive. Phrasal verbs that require an object in a sentence are named as transitive phrasal verbs; without an object, the sentence does not make sense, for example, as in they called off the meeting, she turned down his proposal. On the contrary, intransitive phrasal verbs do not need an object to express their complete meanings, like instances such as the kid is growing up, when do you get up? The other classification considers the separability or inseparability of phrasal verbs. In the sentence, please turn on the light, the verb turn on can be used separately, as in please turn the light on. Unlike the phrasal verb, such as turn on, there are some other kinds, like pass away, which cannot be separated, and the verb and particle remain together, as in the patient passed away. All intransitive verbs are inseparable, but transitive verbs can be either separable or inseparable.

Although some believe phrasal verbs have a one-word equivalent (e.g., show up=brag), it cannot be a precise perception since there are some unique meanings for phrasal verbs. In some cases, there are some connotations for phrasal verbs that a single word equivalent cannot express the precise synonym. Cornell (1985) summarized some instances, such as come by, which has the connotation of struggle (e.g., I cannot believe how he came by that money), and get round, which regularly shows procrastination (e.g., one day he'll get round to repairing that machine). Therefore, sometimes phrasal verbs are not replaceable by their one-word synonym since they carry a specific meaning. Pye (1996) also claimed that, opposing to the common belief that phrasal

verbs are considered more informal than formal, they are very often the most neutral way of indicating something (e.g., break in as in it looked like someone broke in; put away in put your toys away).

Many dictionaries list phrasal verbs with their description and examples of their usage (e.g., Longman Dictionary of Phrasal Verbs, the Collins COBUILD, Cambridge International Dictionary of Phrasal Verbs); however, one essential drawback is that they do not include any detailed information about how frequent a specific phrasal verb is (Gardner and Davis, 2007). Besides dictionaries, several studies have sought to explore the frequency outlines of phrasal verbs. The first step by Biber et al. (1999) was done in Longman Grammar, which included all phrasal verbs with an occurrence of 40 times per million words. As a result of this promising work, a list of 31 most repeated phrasal verbs was established (including some phrasal verbs such as stand up, come on...). Five verbs of come, put, get, go, and take were classified as highly creative to join an adverbial particle to make phrasal verbs. Correspondingly, six adverbial particles were categorized as the most frequent combinations, including up, down, in, out, on, and off.

2.1.3. Phrasal Verbs in a Traditional Approach

Idiomatic expressions and phrasal verbs have not been the point of interest in linguists' research until recently. Although several linguists have attempted to extract the systematic pattern of realizing phrasal verbs in the past. The traditional view has focused on the lexicosemantic interpretation of phrasal verbs' meanings. This view relies mostly on understanding meanings from individual parts of phrasal verbs, regarding little variations in meaning within a larger combination. As Tyler and Evans (2003) claim, phrasal verbs must be memorized with the distinct meanings of their part since they believe the parts (verb and particles) are stored individually in the mental lexicon. Therefore, traditional linguists concentrated more on the syntactic properties of PVs rather than their meaning (Kovacs, 2011).

The traditional view led its practitioners to focus on syntax; they assume the meanings of PVs are arbitrary, and there is unlikely to be a relationship between particles and their impact on the meanings of PVs. As an instance, Fraser (1976) overtly claimed that no semantic feature pertains to PVs and only phonological and syntactic features matter.

Therefore, he gave no weight to particles to carry a meaning in PVs and no role in understanding the meanings of phrasal verbs. It brought up the idea that there is no systematic method to predict the meanings of phrasal verbs with the assistance of their particles. Thom (2017) argues that traditionalists struggled to rationalize the discrete meanings of polysemous phrasal verbs and categorized them simply as homonyms. They believed that the different meanings of a polysemous PV are dissimilar. From this point of view, all native speakers are considered to memorize an individual, unrelated meaning for a particular form of a PV for each distinct meaning.

2.1.4. Phrasal Verbs in a Cognitive Approach

Contrary to the traditional view, the cognitive approach tends to make the functional assumption that “form is motivated by meaning” (Holme, 2012, p.6). Based on this frame, the meanings of PVs are not unrelated and arbitrary. Instead of giving a separate weight to grammar and lexis, this view considers them connected. In the traditional approach, several meanings could be related to one form of word, whereas in the cognitive approach, meaning is considered a dynamic phenomenon as a product of lexis and grammar rather than a static one (Thom, 2017). To summarize the theme of these two different approaches, one can bear in mind that while traditional linguists assume the meaning of vocabulary is arbitrary, cognitive scholars discovered that the meanings are more predictable than was previously thought. How meanings and forms can be associated, to decode this, it is essential to know the impact the conceptual world has on language and interaction. Cognitive linguists believe that human beings form thoughts about the world around them and use language to refer to that; this is the definition of cognition according to their comprehension (Thom, 2017).

Building on this foundation, cognitive linguistics treats phrasal verbs as motivated combinations in which the spatial or metaphorical meanings of particles contribute systematically to the interpretation of the whole unit. For example, the particle “up” often conveys a sense of completion or intensity (e.g., clean up, break up), while “out” frequently suggests emergence or exhaustion (e.g., figure out, run out). These patterns are not random but grounded in our embodied experience and conceptual metaphors, as explained in the work of Lakoff and Johnson (2003). Learners, therefore, can benefit

from being made aware of these consistent image schemas and metaphorical extensions rather than being taught phrasal verbs as isolated idioms.

Recent studies (e.g., Boers, 2021; Condon, 2008) support the idea that learners who are exposed to the metaphorical underpinnings of particles develop a better intuitive understanding of phrasal verbs and retain them more effectively. This supports the view that meaning is not memorized arbitrarily but is shaped through cognitive mapping of space, force dynamics, and goal-oriented actions.

2.1.5. How are Phrasal Verbs represented in the Lexicon?

As mentioned in chapter one, phrasal verbs are always a matter of question for psycholinguists to assume them as one lexical entry or as individual entries that are connected by syntactic rules for native speakers (Jackendoff, 1995). Different attitudes believe in different opinions about phrasal verb representation in the mind, for instance, generativists assume that compositional phrasal verbs, in which both parts have a role in the meaning of the phrasal verbs, cannot be stored. According to Gonzales (2010), the overall meaning of compositional phrasal verbs must be formed during the production and processing of language. By applying the structural priming paradigm, Konopka and Bock (2009) presented some continuous or discontinuous phrasal verbs as prime and then asked subjects to make sentences. The result demonstrated that the subjects tend to produce the same structure that has been presented to them as priming. Their target group was native speakers, and they have shown the same result for both idiomatic and non-idiomatic phrasal verbs.

Undoubtedly, regarding the usage-based approach, the factor of frequency must have been considered, as well (Ellis, 2006; Ellis & Wulff, 2015). In investigating the brain activity by use of magnetoencephalography (MEG), in response to phrasal verbs construction that were both congruent (i.e., cool down) or incongruent (i.e., cool up), Cappelle, Shtyrow, and Pulvermuller (2010) observed Mismatch Negativity (MMN) effects, which were larger than those related to single words and smaller if two connected words were used in the speech. These researchers also added that those

frequently used phrasal verbs are not being built online, but they are stored in long-term memory. In another study by Piai et al. (2013), in which ERP was used, the results revealed one point of access for phrasal verbs as lexicons.

2.1.6. Difficulty of phrasal verbs for L2 learners

Having inspected many studies, the features of phrasal verbs make them difficult for L2 learners to learn. According to Siyanova and Schmitt (2007), since PVs are made up of two or more orthographic words that work together to express a single semantic item, some learners may mistakenly try to decode the meaning of individual words in phrasal verb strings. It makes the difficulty double when they encounter idiomatic and opaque phrasal verbs, which are not decodable from their individual parts in any manner. Additionally, syntactically complex characteristics of phrasal verbs make learners perplexed about which particle can be moved in phrasal verbs and when it cannot. Also, it is mentioned in Garnier (2016) that, though phrasal verbs are frequent in some languages, especially those with Germanic origin, many languages do not have this phenomenon, and learners whose first languages lack this phenomenon face even more difficulties in mastering them in language learning.

One factor that makes phrasal verbs a burden to acquire is that most of them are polysemous. As Gradner and Davies (2007) evaluated, there is an average of 5.6 meaning senses for the 100 most recurrent English PVs and more than 20 diverse meanings just for the phrase go on (White, 2012, p. 1). As a conceptual approach expresses that there is no correspondence relationship between the interpretation of PVs' meanings and their forms (Kurtyka, 2001). The meaning of PVs sometimes becomes polysemous by constant usage; secondary meanings originated from first meanings, which are normally literal. Complex form-meaning relationships for L2 learners are usually made with polysemous senses of phrasal verbs. Considering the verb 'bring up', L2 learners should be aware of the different meanings, which are carry something, nurture a child, or suggest (Biber et al. 1999). Phrasal verbs' meaning often is unpredictable and arbitrary, not being simple to conjecture; PVs are difficult to learn (Walkova, 2012). As it is mentioned in Kovsc (2011), since phrasal verbs are really difficult for EFL learners and they assume there is no rule to comprehend them, they prefer to memorize them.

2.1.7. Avoidance of Phrasal verbs by language learners

The idea of avoidance in second language learning was first introduced in Schachter's (1974) work on error analysis. In that study, she argued that the absence of errors does not necessarily indicate mastery, because learners may simply choose not to use structures they find difficult. Schachter therefore examined not only the forms that L2 learners produced but also the forms they systematically avoided, showing that avoidance can mask underlying problems in acquisition. Building on this insight, many researchers have investigated avoidance in SLA across different linguistic domains and learner populations (e.g., Dagut & Laufer, 1985; Hulstijn & Marchena, 1989; Laufer & Eliasson, 1993; Liao & Fukuya, 2004; Siyanova & Schmitt, 2007; Ben Duhaish, 2008; Ghabanchi & Goudarzi, 2012). Together, these studies have established avoidance as an important phenomenon for understanding learners' interlanguage and their responses to structurally or semantically complex forms.

Because phrasal verbs (PVs) are often considered difficult, many language learners intentionally avoid using them (Dagut & Laufer, 1985; Hulstijn & Marchena, 1989; Liao & Fukuya, 2004; Siyanova & Schmitt, 2007). Avoidance can be defined as a situation in which language learners deliberately decide not to use a particular linguistic form, even when it is appropriate to do so (Schachter, 1974; Kellerman, 1995; Laufer & Eliasson, 1993). One of the earliest empirical studies on PV avoidance was conducted by Dagut and Laufer (1985) with Hebrew-speaking learners of English. Since Hebrew does not have a structure comparable to English PVs, they found that most participants avoided using PVs, especially idiomatic ones, and interpreted this behavior as a consequence of the absence of PVs in the learners' L1. However, as Liao and Fukuya (2004) later noted, Dagut and Laufer did not examine the participants' prior knowledge of specific PVs; therefore, some of the so-called avoidance might have been due to a simple lack of knowledge rather than conscious avoidance. They interpreted that these learners' avoidance is due to the nonexistence of PVs in their L1. Although these researchers did not examine the participants' previous knowledge of such items. Hence, this avoidance manner could have been because of total ignorance (Liao and Fukuya, 2004).

Along similar lines, Hulstijn and Marchena (1989) reported avoidance among Dutch learners, even though Dutch does have PV-like constructions. Their participants tended to avoid opaque phrasal verbs that exist in their L1 but that they perceived as nontransferable into English. By contrast, Laufer and Eliasson (1993) found that, for Swedish learners, the presence of idiomatic PVs with similar meanings in L1 and L2 did not reliably predict avoidance behavior. Further evidence that PVs are problematic and often avoided comes from Liao and Fukuya (2004), who showed that Chinese learners of English consistently underused PVs compared with native speakers, particularly figurative ones, and frequently opted for one-word equivalents instead. Other studies (e.g., Siyanova and Schmitt, 2007; dos Santos Wisintainer & Mota, 2017) likewise suggest that both native and non-native speakers sometimes prefer one-word equivalents to PVs, although questionnaire data indicate that native speakers show a strong tendency to choose PVs over their one-word synonyms. Finally, Waibel (2008), comparing a native corpus of academic essays (LOCNESS) with a corpus of non-native student writing, observed that non-native writers used markedly fewer PVs and relied more often on single-word verbs, a pattern that can also be interpreted as evidence of avoidance.

In Waibel's (2008) study, one-word verbs appeared more frequently than phrasal verbs in ICLE, a non-native corpus. Interestingly, the Dutch and Polish sub corpora did not differ markedly from the native corpus in their overall number of phrasal verbs, whereas the German sub corpus even contained more phrasal verbs than the native corpus. On this basis, Waibel concluded that using phrasal verbs is easier for learners whose first language includes similar structures. However, studies on Persian learners have produced different results. Although Persian also contains phrasal verbs, several studies (e.g., Ghabanchi & Goudarzi, 2012; Barekat & Baniasady, 2014) have shown that Persian speakers of English tend to avoid using English phrasal verbs. This avoidance has been attributed to factors such as the semantic opacity of many English phrasal verbs (especially idiomatic ones), learners' limited exposure to them in input, and a preference for "safer" one-word equivalents that are perceived as more formal and less error-prone.

Building on these findings for Persian learners, Ghabanchi and Goudarzi (2012) ran three tests—a multiple-choice test, a translation test, and a recall test of phrasal verbs—among 85 intermediate and advanced Iranian English speakers. They observed that both groups would rather use literal phrasal verbs than figurative ones, which supports the view that learners prefer semantically transparent combinations and are more likely to avoid opaque, idiomatic PVs. In a related study, Barekat and Baniasady (2014) investigated the effect of phrasal verb avoidance on students' writing ability. At the first stage, they conducted three tests (a multiple-choice test, a recall test, and a verb translation test) to determine the extent to which students avoided phrasal verbs. The participants were then divided into two groups according to their degree of avoidance. One week after the translation test, the participants wrote a narrative essay, and the performance of the two groups was compared. The results showed a significant difference between the two groups' writing: avoidance negatively affected learners' writing, and the group with a higher mean in PV avoidance performed worse than the group with a lower mean of PV avoidance.

Research from other L1 backgrounds further clarifies which factors contribute to PV avoidance. El-Dakhs (2016) noted that cross-linguistic differences, inadequate productive knowledge, and insufficient L2 exposure led to phrasal verb avoidance among Egyptian students. Other studies have indicated that the amount of time learners devote to using the L2 can be a good predictor of progress in mastering PVs (e.g., Garnier & Schmitt, 2016; Schmitt & Redwood, 2011; Zhang & Mai, 2018). In the same vein, Kosolsombat and Pongpairoj (2017) investigated the avoidance behavior of phrasal verbs among L1 Thai learners. They concluded that differences between L1 and L2 can lead to avoidance, with the semantic complexity of PVs emerging as one of the most significant factors.

In addition, Zhang and Wen (2019) focused on learners' comprehension of polysemous phrasal verbs and the aspects that restrict mastery of PVs. The participants in their study were intermediate and advanced Chinese learners of English, who were asked to judge the appropriateness of 100 meanings of 50 phrasal verbs. Both groups showed a clear preference for highly frequent senses of PVs. For advanced learners, factors that encouraged the acquisition of high-frequency meanings included semantic clarity,

frequency of occurrence, years of English exposure, and engagement with English input such as reading books and watching movies.

Research with other L1 backgrounds broadly supports this pattern of difficulty and avoidance. Aziz (2020), for example, examined Kurdish EFL learners' use of English phrasal verbs and reported a strong preference for one-word verbs over phrasal alternatives, especially when the phrasal verbs were figurative or aspectual in meaning. Similarly, in a study of Japanese university students, Okuwaki (2021) found that learners consistently chose single-word verbs more often than phrasal verbs in both multiple-choice and translation tasks, with avoidance becoming particularly evident when learners had to produce the verbs themselves. Building on work such as Zhang and Wen (2019), these studies reinforce the view that learners' underuse of phrasal verbs is not restricted to a single L1 group but appears across typologically diverse languages.

Further evidence comes from studies with learners whose first languages do contain phrasal or particle verbs. Toom (2022), working with Estonian EFL learners, showed that even when the L1 has similar multi-word verb structures, figurative phrasal verbs in English are still frequently avoided, while literal phrasal verbs are used more readily. In a related vein, Rexhepi-Iljazi (2023) reports that Albanian learners of English tend to underuse phrasal verbs and prefer one-word synonyms in written tasks, a pattern attributed to limited exposure, lack of explicit instruction, and uncertainty about register. Taken together, these findings suggest that avoidance is influenced not only by structural differences between L1 and L2 but also by semantic opacity, register considerations, task type, and the amount of meaningful exposure to phrasal verbs (Aziz, 2020; Okuwaki, 2021; Toom, 2022; Rexhepi-Iljazi, 2023).

At the same time, recent pedagogical studies indicate that targeted instruction can mitigate this avoidance tendency. El-Dakhs, Sonbul, and Alwazzan (2021) showed that when EFL learners received classroom instruction that highlighted phrasal verbs and systematically manipulated opacity, learners' gains were greater for more transparent items but extended, to some extent, to opaque phrasal verbs as well. Focusing specifically on figurative phrasal verbs, Tadayonifar, Elgort, and Siyanova-Chanturia (2025) found that contextual learning during reading was substantially enhanced when phrasal verbs were both typographically highlighted and accompanied by definitions,

especially when definitions were accessed after reading. In a complementary line of work, Mustafa and Hirmiz (2024) reported that a cognitive-linguistic approach, which made learners explicitly aware of image schemas and metaphorical extensions underlying idiomatic phrasal verbs, led to significantly better posttest performance than traditional instruction. These studies collectively suggest that although phrasal verbs are often avoided, carefully designed input and form-meaning-focused instruction can help learners notice, retain, and eventually use them more confidently.

2.1.8. Phrasal verb frequency list

Since learning phrasal verbs seem to be tough for L2 learners, and additionally having reviewed the related literature confirmed the importance of learning phrasal verbs and multiword combinations to achieve L2 comprehension in many situations (Moon, 1997 cited in Gardner & Davis, 2007; Wray, 2002; Schmitt, 2004), knowing the most frequent PVs is an asset to both language teachers and language learners. Therefore, the rationale behind the frequency list is to provide the most used PVs in one language to help teachers know what to teach among the huge range of phrasal verbs; after that, language learners can decide what to learn. A frequency list of phrasal verbs is assumed to be one solution to help both teachers and learners to decide which phrasal verbs are more important in terms of frequency to focus on (Liu, 2011). Since the best source for language learning is real life, the best frequency list of PVs is based on an authentic corpus (Schmitt, 2008).

Scholars do not have the same idea about the approximate number of PVs; for instance, McCarthy and O'Dell (2004) referred to more than 5,000 phrasal verbs. Gardner and Davis (2007) believed there are 12508 phrasal verbs. They found that 25 phrasal verbs (e.g., pick up, go on) form almost one-third of all phrasal verb occurrences and 100 more than one-half, which is equal to 51.4%. A drawback of frequent phrasal verb lists, as mentioned by Liu (2011), is that they are made by the top 20 verb-producing lexical verbs. Liu (2011) conducted research based on Biber et al.'s (1999) and Gardner and Davies' (2007) lists. He found a high degree of overlap between these two lists. Liu's search included 8847 phrasal verbs from the dictionaries and 2914 extracted from his own research.

Building on these earlier frequency-based studies, more recent research has attempted to make phrasal-verb lists directly usable for teaching. One influential development is the PHrasal VERb Pedagogical List (PHaVE List), which identifies the 150 most frequent phrasal verbs in COCA and, crucially, specifies their most common meaning senses (Garnier & Schmitt, 2015). This list covers over 75% of all occurrences of those verbs in the corpus and shows that, although phrasal verbs are highly polysemous on average, a small number of core senses account for the majority of their actual use (Garnier, 2016; Garnier & Schmitt, 2015). Such work responds directly to the limitations noted by Liu (2011) by moving beyond simple lemma frequency and providing teachers and test designers with concrete guidance about which phrasal verbs and which senses are most worth prioritising in instruction and assessment.

Frequency research has also become more fine-grained in terms of register and text type. Studies of institutional and academic corpora, for example, show that a relatively small set of high-frequency phrasal verbs dominates usage in specialised domains such as EU documents and academic prose, with substantial overlap with the most frequent items identified in general corpora (e.g., pick up, go on, come back) (Rosca, 2016; Liu, 2011). At the same time, corpus-based comparisons of different formulaic categories indicate that phrasal verbs occupy a distinctive niche alongside collocations, lexical bundles, and idioms, which further supports the need for targeted lists and pedagogical treatment rather than assuming that all multi-word items behave similarly (Garnier, 2016; Paquot & Granger, 2016). More recent work on semantic frequency lists also reinforces the idea that what matters for learners is not only how often a phrasal-verb form appears, but how often particular senses are used in real discourse, suggesting that future phrasal-verb lists will need to integrate both lemma- and sense-level frequency information for maximal pedagogical usefulness (Liu, 2024).

2.2. Second Language vocabulary learning

2..2.1 Vocabulary Acquisition

During many years of learning second languages, it seems vocabulary acquisition has not been paid adequate attention. As Oxford and Scarcella (1994) mentioned, there has been an assumption that L2 learners learn vocabulary by themselves during the process of language learning, and learners will always discover ways to remember new vocabulary without teachers' assistance. Consequently, without surprise, there has not been much time allocated to teach and learn vocabulary in many L2 classrooms, and much effort and time have been given to grammatical learning. However, vocabulary learning has recently drawn considerable attention among teachers and researchers in the field of L2 acquisition (Carter & McCarthy, 1998; Lewis, 1993; Schmitt & McCarthy, 1997; Schmitt, 2000; Nation, 2001; Schmitt, 2010). According to Schmitt (2000), the knowledge of vocabulary has an important role in language learning; a second language learner with an enormous treasure of vocabulary is probably able to interact and apply language more efficiently. Although it has not been an easy process, lexical development is a complicated process.

Lexical knowledge has multiple dimensions. Knowing a word contains not only a semantic feature (i.e., meaning), but also other lexical aspects, such as orthographic, phonological, morphological, syntactic, pragmatic, and collocation (Aitchison, 1994; Meara, 1996c; Nation, 2001; Schmitt & McCarthy, 1997; Singleton, 1999).

Multifaceted knowledge of a word is improbably to be gained in a single encounter. In a study, Stahl (2003) believes it is gradually enhanced and enriched over numerous encounters. For example, a form-meaning connection is generally computed at the initial stages of vocabulary development, while making word networks or applying the words usually occurs at the later stages (Schmitt, 2008). Some researchers and educators have an agreement that lexical knowledge is complicated to define, because there are degrees of knowing a word and many things that can be considered about a single word (Nation, 2013; Nemati, 2013). The process of knowing a word is more complex than only making the connection between its form and meaning (Laufer & Goldstein, 2004).

Therefore, educators have proposed diverse taxonomies for word knowledge. One of the earliest frameworks refers to Richards (1976), who concludes seven aspects of word knowledge:

- To what extent it is possible to face the word in a speech or written passage.
- In which situation and function the word can be used.
- What the related syntax to the word is.
- The basic form of the word and the derivations that can be made from it.
- The associations between the word and other words.
- The word semantics.
- The various meanings the word can have.

The next framework, which has three dimensions, was proposed by Henriksen (1999). The first dimension discusses partial vocabulary learning versus precise knowledge of the word, which illustrates that the word can be learned partially and then developed to be completely known. The second aspect is the depth of knowledge that refers to the brain network's association and link, which the word makes with other words in the network, such as synonyms or antonyms (Ellis, 2015). The more learners manage to make stronger and deeper links between the words and collocations, the more their vocabulary knowledge is enriched, and words are stored in long-term memory (Alahirsh, 2014; Ellis, 2015; Ellis & Beaton, 1993). The third dimension refers to questions about the control or availability aspect of words.

Brown and Payne (1994, as cited in Hatch & Brown, 1995) identified five steps in the process of learning vocabulary in a foreign language: (a) encountering new words, (b) getting a clear image of the forms of the new words, (c) learning their meanings, (d) making a strong memory link between form and meaning, and (e) using the words. Fan (2003) showed that many vocabulary learning strategies can be related to these five steps. However, one of the most extensive and comprehensive models of word knowledge is Nation's (2001) framework, which distinguishes between receptive and productive knowledge. Nation (2001, 2013) further divides word knowledge into three

main categories: form, meaning, and use. This framework is summarized in Table 1 below.

Table 1 Subcategories of word knowledge by Nation (2001, 2013).

Form	Spoken	R	What does the word sound like?
		P	How is the word pronounced?
	Written	R	What does the word look like?
		P	How is the word written and spelled?
	Word parts	R	What parts are recognizable in this word?
		P	What words parts are needed to express meaning?
Meaning	Form and meaning	R	What meaning does this word form signal?
		P	What word form can be used to express this meaning?
	Concepts and references Associations	R	What is included in the concept?
		P	What items can the concept refer to?
		R	What others words does this word make us think of?
		P	What other words could we use instead of this one?
Use	Grammatical functions	R	In what patterns does the word occur?
		P	In what patterns must we use this word?
	collocations	R	What words or types of word occur with this one?
		P	What words or types of words must we use with this one?
	Constraints on use	R	Where, when and how often would we meet this word?
		P	Where, when and how often can we use this word?

Note. R= receptive, P= productive

According to Nation (2001, 2013), knowing the form and meaning of a word needs knowledge of its spoken and written form and knowledge of the connection between form and meaning, relatively. Knowing how to use a word demands knowledge of its grammatical functions. Furthermore, Nation (2001, 2013) emphasized differences between receptive and productive knowledge. According to this theory, both L1 and L2 vocabulary learning is related to all these different levels of word knowledge (Bisson, 2013). This question might come to mind about how learning a new vocabulary in L1 and L2 is different (Barcroft, 2015).

Nation (2013) has an answer to this question, mentioning that the learning burden of a new word, by stating this word demonstrates that how much effort is needed for learning a new word. He believes a word represents patterns and knowledge that may be familiar to learners from their first language, the more familiar it is, and the less effort the learner needs to learn that.

Accordingly, the effort required to learn L2 words differs depending on the individual learner's familiarity with the phonology and orthography of the language, the similarity with their L1, and the regularity of the sound and spelling patterns of the words (Nation, 2013). This justifies that learning new words which is referred to as a burden, is lighter for advanced students because they are already familiar with the phonology and orthography of the language, but much more difficult for beginners, who are new to the area of the L2 (Hakimi, 2014).

2.2.2. How Can Vocabulary be Learned?

Vocabulary can be learned both intentionally and incidentally. The Longman Dictionary (2014) offers the following definition for incidental learning: "1- happening or existing in connection with something else that is more important. 2- naturally happening for the sake of something" (Summers, 2006, p. 775)., while the American Heritage Dictionary (2012) provides two meanings: "1- Done deliberately, intended. 2- having to do with intention".

By engaging these definitions, researchers have classified two modes of language learning: incidental and intentional. Purposefully learning is like rote learning and incidentally can be through communicative activities. In this part, a short description of these two is elaborated, although the emphasis of this study would be on incidental learning. Defining a clear distinction between intentional and incidental vocabulary learning is difficult. Intentional learning of vocabulary often makes learners bored (Min, 2008), and sometimes it is decontextualized like rote learning and learners are not in a rich context (Schmitt, 2008). Hermann (2003) in a study compared learning vocabulary via rote learning and memorization list of words (intentional) and reading a novel (incidental). The results showed that students who memorized vocabulary intentionally outperform those who learned by reading novels, but for short-term not long-term.

Gass (1999) mentioned anything which is called incidental seems to be learned as a product of something else, such as classroom activities or extensive reading. Equally, the research has considered incidental vocabulary learning to be vocabulary learning

that arises when learners are focused on another activity, such as communication, rather than on the vocabulary items themselves (Laufer & Hulstijn, 2001). Incidental vocabulary learning refers to any activity that leads to vocabulary learning but not explicitly (Hulstijn, 2001). In other words, learning can happen without the purpose of memorizing words. In these kinds of studies, learners are often required to perform a task, and they are told that it is to measure their comprehension, although they are going to be tested on the knowledge of unknown words (Hulstijn, 2003). Lexical items can be learned unintentionally through productive means, such as speaking (e.g., Joe, Nation, & Newton, 1996), or writing (e.g., Laufer, 1994). Receptive means, such as reading (e.g., Horst, 2005; Pellicer- Sanchez & Schmitt, 2010; Pigada & Schmitt, 2006; Webb, 2008), or listening (e.g., Bonk, 2000, as cited in Schmitt, 2008; Elley, 1989; Vidal, 2003), are also efficient methods of enhancing lexical knowledge incidentally. There are some merits and demerits for incidental vocabulary learning, although it is the combination of two concurrent activities (e.g., reading and vocabulary learning) and it supports learner- centered learning process, it has some disadvantages, as Schmitt (2008) mentioned that it is time-consuming and produces a small range of vocabulary.

Researchers are inclined to agree that native speakers acquire most of their vocabulary incidentally through communicative activities - that is, word learning from context (Jenkins, Stein, & Wysocki, 1984; Nagy & Anderson, 1984). Some evidence in L1 empirical research has depicted that although vocabulary gain through reading is less, it is significant. Learning (Swanborn & de Glopper, 1999). Some additional process of word learning is needed for these low gains to be learned (Nagy, Herman, & Anderson, 1985; Stahl, 2003). Therefore, as Strenberge (1987) stated, learners benefit from extensive reading, and learners who are exposed to words repeatedly develop their lexical knowledge successfully by incidental means.

2.2.3. Explicit and Implicit Learning

According to Ellis (2015), implicit learning is the acquisition of knowledge about the underlying structure of a complex stimulus environment by a process that takes place naturally, simply, and without conscious operations. Explicit learning is a more

conscious operation where the individual makes and tests hypotheses in a search for structure (p. 2).

Likewise, Schmidt (2001) described implicit learning as learning without awareness and explicit learning as learning with awareness. By referring to consciousness and awareness, it is possible to distinguish the distinction between incidental and implicit learning. Schmidt (1990, 2001, 2012) outlined the issue in terms of consciousness as intention, consciousness as attention, and consciousness as awareness. He further claimed that “consciousness as intention is reflected in the distinction between incidental learning, referring to the fact that people can learn things without having any particular intention to learn them, vs. intentional (goal- directed) learning” (2012, p. 724). Concerning consciousness as awareness, Schmidt (2012) emphasized the fact that abstract knowledge of grammar “cannot be a prerequisite for learning”, because native speakers, and advanced L2 learners, have some ‘intuitive’ comprehension of the indirect aspects of grammar, rather than the fundamental ‘rules’ that are taught in language classrooms. Accordingly, in this case, psychologists usually use the term ‘implicit knowledge’, “knowledge that is acquired without conscious effort to learn, without awareness that learning has occurred, and without the ability to describe the acquired information” (Reber, 1993, as cited in Schmidt, 2012, p. 725).

Having in mind what Schmidt (1990, 2001) and Ellis (1994) claimed, Reider (2003) supposed that if consciousness relates to intention and is defined as awareness, then implicit learning happens in the absence of consciousness, and explicit learning in its presence. Thus, incidental learning is associated with ‘un- unintentional’, which is to say without any restrictions as to the role of awareness, and the term ‘implicit’ is associated with ‘nonconsciousness’, in the sense of ‘unawareness’. As research has illustrated, the notions of incidental and intentional should not be perplexed with the concept of implicit or explicit learning, as they believe explicit learning can take place both incidentally and intentionally; however, implicit learning only happens incidentally (Laufer & Hulstijn, 2001).

It seems that the concept of ‘incidental’ is closely related to the term ‘attention’. According to Hulstijn (2001), the degree of learners’ awareness of whether they know the purpose of the post-reading vocabulary test, while they are learning, can be a factor

to distinguish the definitions of incidental and intentional learning. In the incidental condition, subjects are not told they will be tested on the given material, while in the intentional condition, they are told (Wesche and Paribakht, 1999). What caused this consideration, as noted by Hulstijn (2001), are complex processes involved in these two modes of learning and their conditions, although the common definition for incidental learning is learning one thing while intending to learn something else (Richards & Schmidt, 2002).

This definition of incidental learning appears to be in line with Krashen's (1989), which claims that language can be acquired only by figuring out the message in a discourse by the power of comprehensive input and incidental learning, which Krashen named 'acquisition'. Accordingly, acquisition occurs when language learners' attention is focused on grasping the meaning of the message. Some educators assign these procedures of incidental acquisition as a 'by-product', not the goal of other activities that are included in comprehension, such as reading (Gass, 1999; Huckin & Coady, 1999; Wesche & Paribakht, 1999). It is required that the new word be repeatedly encountered in diverse comprehensible passages, so that incidental acquisition takes place.

Conversely, this by-product description of incidental learning has some critics (e.g., Gass, 1988; Ellis, 1994; Schmidt, 1994) who believe that the by-product common definition seems to ignore any active role of the learner during the learning process. Moreover, it has been discussed that attention to unfamiliar vocabulary is essential for any incidental learning to happen (Gass, 1988; Ellis, 1994; Schmidt, 1994). Laufer and Hill (2000) stated that there is an enormous body of research evidence that L2 learning, and principally adult L2 learning, does not occur without a degree of awareness (Schmidt, 2012). If consciousness is related to intentional learning, Ellis (1994a, p. 38) claimed that "incidental learning should be used to refer to situations where individuals learn without intent to learn, or when individuals learn one thing when their primary objective was to do something else".

As it has been reviewed, incidental learning of vocabulary, as referred above, is a byproduct, for example, activities outside the classroom or extensive learning, unlike

intentional vocabulary learning that involves those activities like memorizing a long list of vocabulary and sometimes a decontextualized list of words (Barcroft, 2015; Hulstijn, 2001; Laufer & Hulstijn, 2001). Based on this approach, incidental vocabulary acquisition is sometimes erroneously supposed to be unattended learning (Nemati, 2013).

Ellis (1999) distinguishes between ‘peripheral’ and ‘focal’ attention as another differentiation between incidental and intentional learning. They claimed that in the incidental/implicit learning circumstance, most attention goes to understanding the meaning of a message, while a degree of attention is allocated to focusing on the form.

Whereas, in the intentional/explicit learning kind, the learner’s focal attention is deliberately focused on the language, and specifically on creating an association between form and meaning. Correspondingly, Schmidt (1990) stated that a certain degree of consciousness is involved in the incidental learning process that occurs when a learner ‘notices’ a new word. According to Barcroft (2015), lexical input processing will happen whether the new word is acquired incidentally or intentionally. Subsequently, learning always needs a degree of attention, and without attention cannot occur, regardless of being incidental or intentional.

After reviewing the literature related to learning vocabulary in both first and second languages, it appears that most of the vocabulary learning occurs incidentally as a result of gradual experience and input. Hence, some researchers believe that a large amount of vocabulary learning is acquired incidentally, for example, during extensive reading, and only a small amount of it is learned through direct intentional learning (Alahirsh, 2014; DeKeyser, 2008; Huckin & Coady, 1999; Nagy, Herman, & Anderson, 1985). Learning vocabulary through reading is one of the methods of vocabulary learning, which is contextual for enhancing lexical knowledge and skill areas (Allothman, 2014; Schmitt, 2010b). The skill of guessing the meaning of an unknown word is another advantage of incidental vocabulary learning (Nation, 2007; Nation, 2013).

Nonetheless, there are several limitations of incidental vocabulary learning. Some studies have depicted that when it comes to guessing words, not always lead to acquiring the meaning of new words from reading (Laufer, 2005; Sokmen, 1997). As Nation (2001, 2013) mentions, the number of vocabulary items acquired incidentally from reading or context is small, due to different reasons such as 'variability' that a passage must have to simplify learning. Also, the frequency of encountering the new word should be at least 6 to 20 times, as Zahar, Cobb, and Spada (2001) believe. Likewise, Nation (2001) states the significance of the frequency of the new word, and he states that 5 to 16 exposures are needed. In addition, the passage must be rich and informative to facilitate guessing and learning (Nemati, 2013). Learners must have a good knowledge of guessing strategies not to infer the incorrect meaning (Schmitt & McCarthy, 1997). Also, Schmitt (2008) believes incidental vocabulary learning is time-consuming and results in a small amount of learned vocabulary. Advanced learners of L2 outperform the meaning of new words in a passage than beginners (Gu, 2003; Nemati, 2013).

Consequently, learners at later stages of their language development are assumed to be more capable of learning vocabulary incidentally than beginners, and more capable of conjecturing words within authentic contexts. Another limitation, according to some studies (e.g., Carter & McCarthy, 1988; Schmitt, 2010b; Web, 2008), is that while incidental vocabulary acquisition involves profound engagement, it takes longer for a word to be encountered naturally than it does in a structured lesson; therefore, L2 learners must increase their reading volume to ensure sufficient exposure. Although incidental vocabulary learning has some benefits. It offers a richer comprehension of the contextual meaning and use, allows two contemporary activities (e.g., reading and vocabulary learning), and develops a learner-centered learning procedure (Huckin & Coady, 1999; Shahrokni, 2009).

Ellis (2015) believes that intentional or explicit learning is a conscious process. It requires the application of vocabulary learning strategies on the part of the learner (Segler, 2001). The core of Krashen's model, which both models of learning take place, was shaped according to the distinction between implicit and explicit learning. One of the important features of intentional vocabulary learning is focused attention (Barcroft, 2015). The more attention a learner pays to morphological, prosodic,

semantic, and pragmatic features, the more likely it is that the new lexical knowledge will be retained (Hulstijn, 1993). It therefore seems that intentional vocabulary learning is a basic approach, while some explicit and cautious vocabulary learning might be necessary as a prerequisite for acquiring L1 and L2 vocabulary incidentally through reading and listening (Schmitt, 2000). It has been recommended that certain intentional learning is essential for L2 learners to attain a vocabulary 'threshold' that enables vocabulary learning to happen incidentally through reading (Schmitt, 2000). According to Grabe and Stoller (2013), any deliberate word activity should focus on the 2000 to 3000 most frequently used words in a language to build a fundamental foundation for the automaticity of word-recognition. Nielson (2006) states that at the initial steps of language development, de-contextualized vocabulary learning has been proven to be more efficient in building main vocabulary than contextualized reading. He stated that teaching and learning of L2 vocabulary should start with a decontextualized list of vocabulary, and the process of word development gradually moves toward a context-based form of vocabulary learning.

To sum up, advanced learners of a language who are at the later stages of their language progress are expected to be capable of learning words incidentally, and they likely are good word guessers in a context. Although some researchers (e.g., Allothman, 2014) state that this belief would result in the limitation of explicit vocabulary teaching to advanced language learners. Likewise, texts may not provide adequate opportunities for repeated encounters with vocabulary (Matsuoka & Hirsh, 2010; Milton, 2009). Thus, there is no unified opinion about modes of vocabulary learning for advanced language learners (Allothman, 2014; Nation, 2013). Furthermore, it has been recommended by many scholars that incidental learning should not be selected as a fundamental approach for learning L2 vocabulary, as it does not seem to be a functional method by itself; rather, it should be complemented by a degree of intentional learning, and both learning modes should be considered to boost the other (Alahirsh, 2014; Nation, 2013; Schmitt, 2008).

2.2.4. L1 and L2 Incidentally Vocabulary Learning

Since the early 1980s, L1 incidental vocabulary acquisition from reading has drawn the attention of many scholars (Saragi et al., 1978; Jenkins et al., 1984; Nagy et al., 1985; Nagy et al., 1987). Classic L1 studies such as Saragi, Nation, and Meister's (1978) *A Clockwork Orange* experiment showed that native speakers could pick up a substantial number of unfamiliar words simply by reading a novel, especially when the words occurred repeatedly.

Jenkins, Stein, and Wysocki (1984) likewise demonstrated that children incidentally learned new word meanings from specially constructed texts, with learning increasing as the number of encounters with the target items increased, while Nagy and colleagues' large-scale classroom studies (Nagy et al., 1985, 1987) estimated that school-age children acquire thousands of new words per year largely through incidental encounters in reading. Parallel lines of research in L2 have shown that second-language learners can also acquire vocabulary incidentally from meaning-focused input such as reading graded readers or authentic texts (e.g., Pitts, White, & Krashen, 1989; Day, Omura, & Hiramatsu, 1991; Horst, Cobb, & Meara, 1998; Waring & Takaki, 2003; Brown, Waring, & Donkaewbua, 2008), although the gains are typically smaller and require many more encounters with each new word.

More recent L2 research has refined this picture by examining a wider range of input types and by looking more closely at how much and what kind of vocabulary is picked up incidentally. Case studies of extensive reading, such as Pigada and Schmitt (2006), have shown that sustained reading of graded or simplified texts can lead to substantial gains not only in word meaning but also in spelling and grammatical knowledge, particularly when learners meet target items repeatedly. Large-scale extensive reading projects with audio support likewise suggest that learners can acquire a sizeable number of new words incidentally through reading and listening to multiple graded readers, even though frequency and distribution of occurrences are only part of what drives learning (Webb & Chang, 2015).

Eye-tracking work has added a process dimension, showing that learners tend to fixate longer on unfamiliar words and that greater attentional allocation during reading

predicts larger vocabulary gains (Pellicer-Sánchez, 2016). Beyond print, studies of viewing L2 television provide further evidence that incidental vocabulary learning occurs from audiovisual input, with the amount of learning influenced by factors such as frequency of occurrence, prior knowledge, and cognateness (Peters & Webb, 2018). Finally, recent review work (Zuo & Yan, 2019) indicates that across the last two decades, incidental vocabulary learning from reading remains a robust finding, but outcomes are systematically affected by variables such as learner proficiency, text difficulty, and the number of encounters with each new word.

Consequently, there is an agreement that most L1 vocabulary is acquired incidentally from exposure at early stages from verbal communication with their parents and at later stages, text exposure. Some scholars (Nagy & Anderson, 1984; Goulden et al., 1990; Nagy, 1997) have estimated that L1 learners acquire almost 1,000 new words every year. Goulden et al., (1990) estimated that by the time L1 learners enter university, they know about 20,000-word families, and a higher suggestion refers to Nagy and Anderson (1984), who suggested students between grades three and twelve learn about 3,000 words and increase the number to 40,000 at the end of high school. Having borne these estimations in mind, although scholars don't have an idea of the size of vocabulary L1 learners learn, just a small part of vocabulary is learned directly, and a large portion of it is considered to be acquired incidentally through texts. (Day et al., 1991).

While experimental evidence in L1 study has discovered small, but noteworthy, vocabulary gains from reading (Swanborn & de Glopper, 1999), these low gains are assumed to be provided by the growing process of word learning (Nagy, Herman, & Anderson, 1985; Stahl, 2003). Carey (1978) claims that if any lexical learning from context occurs, it must be considered as incidental. This opinion further suggests that vocabulary learning is gradual in nature. Nagy et al. (1985) explain that incidental acquisition of first language vocabulary can be meaningful as long as this gradual process is further improved by exposure to written language. Bearing these considerations in mind, it can obviously be perceived that incidental learning from context, and especially from reading, has a significant role in first language acquisition. L1 research, therefore, values the advantage of extensive reading for vocabulary development (Sternberg, 1987). As learners are exposed to words repeatedly, they grow

lexical knowledge efficiently by incidental processes. Such results made many scholars attracted to apply this idea to second language acquisition.

This phenomenon motivated many researchers to try to use similar approaches in the area of second language acquisition. Krashen (1985, 1989) offered the Input Hypothesis, suggesting that comprehensible input naturally drives towards second language acquisition. Though this hypothesis has been disputed (Laufer, 2005a; Raptis, 1997) for two important reasons. Firstly, unlike native learners who have better chances of repeated exposure to words in multiple contexts (Stahl, 2003), exposure to the target language is limited for learners in an L2 learning context (Stoller & Grabe, 1993).

Martin (1984, as cited in Folse, 2006) has noted that, "the luxury of multiple exposures to words over time and in a variety of meaningful contexts, is denied to second and foreign language students" (p. 130-131). Furthermore, trusting only on naturally occurring incidental learning may be too time-consuming, since it might take L2 learners "a year to acquire at best 200 words from reading" (Laufer, 2005a, p. 22), on condition that input is comprehensible. Secondly, whereas L1 learners fruitfully acquire words incidentally through figuring out meanings from contexts, L2 learners are normally unsuccessful in inferring meanings properly due to the insufficiency of their target language ability (Kelly, 1990).

In many studies, incidental vocabulary learning occurred by using extensive readings or short texts (e.g., Pitts et al., 1989; Dupuy & Krashen, 1993; Horst et al., 1998; Rott, 1999a). Recently, however, studies have focused on incidental vocabulary learning through extensive reading (e.g., Horst, 2005; Pigada & Schmitt, 2006; Al-Homoud, 2007; AlHomoud & Schmitt, 2009). In these kinds of studies, participants are exposed to a different number of texts of various levels, including both short texts and long texts. In spite of some criticisms on the drawbacks of these studies in terms of methodologies, they have reported remarkable incidental vocabulary gains.

2.2.5. Studies on Incidental Vocabulary Learning Through Reading

In this section, studies on incidental vocabulary learning are considered since incidental vocabulary learning is related to the present study. Regarding the second and foreign language vocabulary acquisition, many studies have examined the incidental acquisition of lexical items through reading (e.g., Brown et al., 2008; Day et al., 1991; Dupuy & Krashen, 1993; Horst, 2005; Hulstijn et al., 1996; Kweon & Kim, 2008; Pellicer-Sánchez & Schmitt, 2010; Pigada & Schmitt, 2006; Pitts et al., 1989; Rott, 1999; Saragi et al., 1978; Vidal, 2011; Waring & Takaki, 2003). As noted before, this model of learning is often mentioned to involve learning from context, since the meaning of new words is supposed to be understood from the traces in the passages with the assistance of other concepts around the new lexical item in a sentence and passage.

Saragi et al. (1978) conducted one of the earliest studies that investigated incidental L2 vocabulary learning from reading. They asked 20 native English participants to read the novel 'A Clockwork Orange'; it was almost 60,000 words long, including 241 Russian slang words (nadsat). To assess incidental word learning from reading in this study, Saragi et al. (1978) tested 90 of the Russian slang words. Incidental gains in this study were measured through a multiple-choice test. After the reading, the subjects were supposed to select the appropriate meaning for each of the nadsat words from choices of four English words. The remarkable results have revealed that the average score for learning of the 90 nadsats from reading the novel was 76%, with a 77% median.

The results drew the attention of some other researchers like Pitts et al. (1989), who repeated Saragi et al.'s study by requesting two experimental groups of ESL learners (containing 35 and 16 subjects respectively) to read the first two chapters (about 6700 words) of 'A Clockwork Orange' for about an hour. After a 10-minute break, the investigators examined their participants' knowledge of 30 nadsats appearing in the chapters. At the same time, two control groups, of equal numbers (23 subjects), had the multiple-choice post-test with the experimental groups. Pitts et al.'s (1989) findings indicate that adult ESL learners were able to show a small but statistically significant incidental gain in vocabulary knowledge when compared with the control

groups. The first experimental group scored 6.4% ($M=1.8$, $SD= 28$) on the post-test, while the second experimental group scored 8.1% ($M=2.42$, $SD= 30$).

One of the other studies on incidental low gain of vocabulary through reading text has been done by Day et al. (1991). They conducted a study of two groups of 191 high school and 397 EFL students from Japanese universities. Researchers randomly classified the students in treatment group and the control group. The researchers identified the unknown target vocabularies through a pilot word test, which was given to a group with the same characters. A word was eliminated from the post-test if it had gained more than 40% correct responses. The participants in the two treatment groups read, in 30 minutes or less, an abridged version of a story called “Mystery of the African Mask” (1,032 words). The subjects were given a multiple-choice post-test consisting of 17 words right after they finished the reading. Two control groups, who had not read the story, were given the test too. The participants were not allowed to use dictionaries and were asked not to guess the meaning of unknown target words. Instead, they were asked to select “I don’t know” when appropriate. Neither the treatment nor the control groups were informed that they would have a vocabulary test. The findings from Day et al.’s (1991) study depicted that the subjects in the treatment groups knew significantly more words than those in the control groups. The difference between the mean scores of the university treatment group ($M= 9.34$, $SD=3.41$) and the control subjects ($M= 6.28$, $SD=2.97$) was statistically highly significant, $p<0.01$. Similarly, the high school subjects in the treatment group scored significantly higher marks ($M= 5.02$, $SD=3.21$) than the subjects in the control group ($M= 4.01$, $SD=2.48$), $p<0.01$.

Meanwhile, the rate of incidental vocabulary learning in the research by Dupty and Krashen (1993) was reported to be much higher. A group of 42 undergraduate students was the subject of this research. In this study, there were two control groups and one experimental group. The members in the experimental group were asked to watch the first five scenes of a play named ‘Trois homes et un couffin,’ and the next day they would have a forty-minute task including the reading passage of the next five scenes. In this study, the play was shown without subtitles to avoid the subjects from noticing any unfamiliar lexical items. Like many studies, the subjects didn’t know they were to

be tested on their vocabulary after the play. The test was in multiple-choice format. The test had several words that appeared in the text and repeated occurrences of 30 words from one to six times. Some native French speakers selected these colloquial words to avoid the chance of being known by the subjects. All subjects in all groups accomplished the vocabulary post-test right after the experimental group had read the text. Relative to the control group, which had neither seen the text nor watched the movie, Dupuy and Krashen (1993) discovered that the average gain of the experimental group was nearly 6 words, which suggests that almost 20% of the unknown words were acquired in just 40 minutes of reading.

Some of these studies analysed the impact of frequency of a new lexical item in a context, which differed from one exposure to more than twenty exposures. For instance, Hulstijn et al. (1996) applied three conditions of marginal glosses, dictionary use, and reoccurrence of unknown words in the reading passage. These researchers grouped the 78 subjects who are advanced Dutch learners of French into three groups: Marginal glosses, Dictionary, and a control group. They provide L1 translation of news words for the first group of learners, including 16 target words and 16 extra words from outside the reading. The second group was permitted to look up in the dictionary while reading, and those participants in the control group enjoyed neither of the two previously mentioned supports during their reading. The authors used a short story text, which was modified with 16 target words in the margin for the first group.

The authors in the learning stage asked participants to spend 25 minutes reading the text. Since the study was supposed to be conducted on incidental vocabulary learning, to meet its special conditions, they told the participants that they would be checked only on their comprehension of the text, not on their knowledge of words. Consequently, applicants focused on the perception of the meaning of the whole text rather than on new words. However, at later stages, researchers tested the vocabulary knowledge of participants. Hulstijn et al. (1996) ran three post-tests, to test three different knowledge areas of vocabulary; firstly, a recognition and recall test of marginal unknown vocabularies, second, students' pre-known words, and third, target words in the context. The results of this study demonstrated that the number of occurrences of target words in the passage from 1 to 3 times significantly facilitated incidental vocabulary learning

in three groups of marginal glosses, dictionary, and control. The only drawback of this study was that it did not test the participants' pre-knowledge of the target vocabulary before running the learning phase by reading, but it did so after the reading phase. Also, the study did not investigate the long- term uptake of the words.

Concurrently, Rott (1999) directed research including 67 intermediate German language students studying an American university. He composed some short paragraphs of up to six sentences, including new words. L2 students read them once every week. Learners were divided into three groups to examine different treatments, for instance, the impact of exposure frequency (two, four, and six times) on the learning of the target words. Unlike the study mentioned in the previous paragraph, in this study researcher ran a pre-test vocabulary exam to confirm that the target words were unknown to the participants. Rott used a list of 50 words, including the 12 target words and 38 distractors. The participants were to write the meanings of those words they know and pass the ones they do not know.

To access the learners' knowledge of target words, the researcher ran two post- tests, a productive and receptive vocabulary test. The subjects were to write the definitions for the first type and select the correct answer for the latter type of test. According to the findings of this study, two exposures facilitated the learning of the target word compared with the control group. However, the subjects who had been exposed to target words six times outperformed the other two groups, who were exposed to new words two and four times, as his study demonstrated that incidental learning can take place after several exposures to new words in the context.

Meanwhile, there was a study by Waring and Takaki (2003) in which 15 intermediate Japanese learners of English were to read and enjoy a graded book. Waring and Takaki (2003) were concerned with incidental vocabulary learning through reading. They chose an easy reading at a lower level of the subjects to ensure that the passage included understandable adjacent vocabulary to help the student to infer the target word meanings. The target words' frequency was from one time to 18 times in the reading. The authors used three different tests, including yes/no questions, multiple-choice tests, and a definition test, to investigate the effect of frequent exposure to target words. The

three tests were run three times during the three-month course; the first one was run immediately after finishing the reading, the second one after a week, and the third one after three months.

Another research conducted by Pigada and Schmitt (2006) assessed the incidental word learning in extensive reading in terms of various aspects of words, including meaning, form, spelling, and grammatical behaviour. In this case study research, a Greek native speaker who was studying French was the subject. Before testing his incidental acquisition of vocabulary, he was asked to do an extensive reading of graded readers for one month. Next, to examine his knowledge of 133 target words, an interview with the participant was planned before and after the reading. The target words consisted of 70 nouns and 63 verbs, and were classified into six frequency groups of one, two to three, four to five, six to 10, 10 plus, and 20 plus occurrences. The subject did not know the aim of the study. Two kinds of pre- and post-test tests were administered, the first day a spelling test was taken, and the second day the meaning and grammatical use test. Also, the researchers transformed the word order in the meaning and grammatical use tests to prevent parallelisms in the test form.

According to the results, participants showed a 65% improvement in at least one of the tests, and their spelling significantly improved from 37% to 60% in the post-test. One other noteworthy result was that knowledge of nouns was better enriched than knowledge of verbs in all groups. The minimum learning report was for nouns, which were repeated one, two, or three times, although in other groups, participants' word knowledge developed. Also, participants did not acquire target verbs that were repeated only once in a text. The findings of this study were in line with Waring and Takaki's (2003) but differed from those of Rott (1999), in that incidental learning can take place through a small number of exposures.

In further studies of incidental vocabulary learning, Pellicer-Sánchez and Schmitt (2010) asked their subjects to read a 150-page novel, including 34 unknown target words. They divided the target words into 5 groups in terms of exposure to the words, varying from one to 28 occurrences. After having finished the novel by the subject, they were administered four different kinds of vocabulary tests to investigate their knowledge of spelling. Word class, meaning, and meaning recall. The results depicted

that nine of the target words were the most words which were acquired, and the occurrence of these words was more than ten times; the words that appeared in the text more than ten times were remembered more than the words that were repeated less in the text. The same result as it can be seen in Pigada and Schmitt (2006) and Waring and Takaki (2003).

One of the valuable studies in this area was carried out by Horst (2005). In her pilot study, she investigated the incidental vocabulary learning of 21 EFL learners with various L1s. They had different proficiency levels from elementary to upper intermediate. They went through six weeks of an extensive reading period. During this period, they access the mini library of 70 different simplified books in various levels and genres. In Horst's research, unlike many other researchers, in which the subjects read the same text, the participants read a wide range of texts; therefore, to investigate the amount of word knowledge, Horst (2005) had to pre- and post-test the subjects individually. She decided to scan 12 readers electronically, using two books from each level. Because scanning the whole book was extremely time-consuming, Horst scanned only the first 20 pages of each book by the use of lexical frequency profiling software. To measure pre- reading vocabulary knowledge, she administered a modified version of the test that she and a colleague used in an earlier study (Horst & Meara, 1999). The self-report pre-test includes 100 words arbitrarily selected by 12 readers: 50 words from the 1001-2000 most frequent words and 50 out of the off-list words. The researcher omitted words from the 1000-word list and the Academic Word List from the test to prevent the subject from encountering probable familiar words. The checklist was administered as a pre-test before the participant went through the texts. They were asked to choose Yes if they knew the words, Ns (not sure) for those who are familiar but they are not sure, and NO if they did not know the meaning.

Then, the subjects went through the six-week extensive reading period. During the program, the participants could choose the books according to their interests and levels. Additionally, they were permitted to borrow a book, which they liked to read at home. To improve extensive reading, the researcher ran one hour of reading sessions per week, including some reading and vocabulary tasks. Horst scanned the first 20 pages of each new title during the experiment period. Later, she managed to scan 37

of the more frequently borrowed (among learners) titles, which increased to 159 of 222 books during six weeks. The post-test was designed individually, and the researcher made lists of words occurring in 37 titles. Each post-test was created completely from items appearing in four of the titles read by the subjects during the experiment period. The post-test was individualized with three choices of YES, NS (NOT SURE), and NO. To estimate any development in vocabulary knowledge, Horst compared the number of words that a participant had evaluated YES on the pre- and post-tests. According to Horst's (2005) result, in post-test mean increased significantly in 1001-2000 most frequent words ($M = 6.59$, $SD = 5.47$) and words from the off-list group ($M = 10.29$, $SD = 7.62$). This indicated a new acquisition of seven words from the first list and ten words from the off-list items. Altogether, the participants acquired half of the words, which were rated NO in both groups, after extensive reading treatment. Horst (2005) believed the results of the off-list group might be more reliable.

Like any other research, Horst's (2005) study is not flawless; firstly, due to not being able to completely scan 70 books, she chose the target words from the first 20 pages of each book. And it obviously cannot characterize all words in the book. Also, Horst selected two different checklists to give to their participants as pre- and post-test; this can affect the measurement of incidental new word gain from the reading. It might be better to have asked the participants to choose the titles they like to read during the six weeks before. It would have facilitated the identification of the target words from what the participants preferred to make the same list for pre- and post-test. Additionally, having had some paired reading tasks and activities could have drawn the participants' attention to the target items.

Like Waring and Takaki (2003), Brown et al. (2008) applied multiple testing instruments to measure incidental learning and retention of words over time. In their research, they used two types of tests multiple-choice and meaning translation tests. In multiple-choice tests, there were three options, including the correct answer, three distracting words, and 'I don't know'. These tests were administered three times to be able to measure retention rates: the first test was taken right after the experiment, the second test was taken one week later, and the third one three months later. The translation test was taken before multiple tests in order to prevent any transfer of knowledge and also, the subjects of different groups went through the test separately.

In this research, there were three different input modes, including reading, listening, and following reading-while-listening tasks, to collect data from all the subjects, regardless of what kind of input they were exposed to, who were tested immediately after finishing their tasks. Then, after one week and three months, tests were implemented. Though in the sixth week, following each group's final experimental input, the subjects were immediately asked to do the vocabulary tests. One week later, researchers asked the subject to write a short article about their impressions of the experiment, including their feelings about the stories and their preferred input mode.

Brown et al. (2008) discovered that incidental vocabulary learning was shown by the instant post-tests for all three input taking groups. Regarding the input mode, the quantity of learning was different; subjects who went through reading and reading while-listening outperformed and demonstrated a higher amount of learning compared to the subjects who only received listening input. The former groups had an average of 13.31 and 12.54 and in the latter group, they had a mean of 8.20. Also, the higher mean in recall tests shows the better performance of the participants in reading (4.39) and reading-while- listening (4.10) than only listening (0.56). Brown et al. noticed there was a small drop in the mean scores obtained by three groups after the third test. They found that only one word was recalled from the reading-while-listening and reading alone modes in three months, but no words were remembered from the listening alone mode. The results are in line with Waring and Takaki (2003), who believed the rate of incidental vocabulary learning is highly dependent on the way the learners are tested.

Meanwhile, in a study, which was conducted by Al-Homoud and Schmitt (2009), they applied a more genuine, extensive input. In this study, researchers investigated the impact of two modes of reading approaches (extensive and intensive) on a few language skills, such as incidental vocabulary learning. In this research, 70 novice EFL learners took part, although their level was various, researchers selected among novice learners. Then they divided the subjects randomly into an intensive group with 23 members and an extensive group of 47 members. An instructor taught a reading course to intensive group participants. The classes were four classes of 50 minutes long per week during the experiment; they lasted for 10 weeks. So, every week, the students in

the intensive group received explicit teaching of 80 to 120 new words from the passage they read in class. In total, the group read about 100 pages during the experiment time. Also, the intensive group learners were asked to do some comprehension tasks at home as homework.

The extensive group participants were treated differently compared with the intensive group; the members of the extensive group were exposed to 150 graded books that were chosen with a vast range of variety in terms of genres, titles, and publishers. Also, they were varied in subject matters and language proficiency level (level 1 to 6) to fit all participants' levels and interests. The participants of the extensive group took their reading sessions in the classroom while one of the researchers supervised them. Researchers provided a bookshelf with six different colors; each color goes to a different level, and they brought the shelf to each reading session in the class for students to choose the book they liked. The member of the group, who were supposed to be tested in vocabulary learning, were asked to choose a book one level beyond their level. Throughout the experiment, the participants read diverse amounts of text, with those who read books from the higher levels reading more pages every week than those who selected lower-level books.

Al-Homoud and Schmitt (2009) perceived that all participants could read one book per week after three weeks of extensive reading classes, regardless of the different levels. They assessed that, by the end of the treatment, the learners of the higher level could read about 162,000 words, while readers of the lower level could read noticeably fewer, around 31,500 words in all reading meetings. Then, to measure the amount of vocabulary knowledge, the participants were asked to take the two versions of the Vocabulary Test (designed by Schmitt et al., 2001). The researchers revealed that extensive reading accelerated learners' incidental learning of vocabulary to a similar number of new words, which were acquired by intensive reading groups. Both groups excelled in terms of their vocabulary knowledge. Al-Homoud and Schmitt (2009) also found that the more the occurrence of a word in text, the more learning occurred in both groups. They computed that the extensive group learned 5.57 words, while the intensive group acquired 6.57 words per day out of the 2000 level.

Pointing to what Horst (2005, p.362) mentioned, that “word knowledge measures administered before and after an extensive reading treatment should feature words that participants have actually met in their reading”; one of shortcomings of Al-Homoud and Schmitt’s (2009) study is that they did not display how many of the newly acquired words truly occurred in the graded books that their subjects read. Since they only investigated the size of learners’ vocabulary knowledge. Besides, the researchers did not exclude the doubtful effect of other L2 input sources to which the readers were exposed. The results would be more dependable if the participants were pre- and post-tested by the set of target words of their reading passages, compared to a control group, to eradicate the probable influence of other input sources.

In the area of incidental vocabulary learning, a case study was conducted by Furuta (2012); the subject was a Japanese ESL learner in the USA. This study also showed the occurrence of vocabulary incidental learning through extensive reading. In this research, Furuta (2012) asked the participant to highlight any unfamiliar words in the text while reading, including some words that she looked up in a dictionary, and annotated them in the text. There were 116 words that were highlighted as unknown words by the subject. The participants looked up 36 new words in the dictionary. In order to estimate the incidental vocabulary learning from reading, Furuta (2012) used a self-report checklist of 116 words. One week after having finished the reading, the subject was supposed to take the test. In the test, three options were administered: 1) yes if the subject knew the meaning; 2) NS (Not sure), if she was not quite sure, although the word seemed familiar, and 3) No if the subject did not recognize the word.

The results from this case study significantly advocate the role of reading in enhancing the L2 incidental vocabulary knowledge. As data showed, the subject learned about 35% of the unknown words after reading two chapters of the book. Since the subject was an ESL learner in the USA, to consider the likely effect of the exposure to L2, Furuta (2012) applied online software to analyse and classify the target words according to their frequency of use in English. To make the findings more reliable, the researcher investigated the low frequency words, because such words had little opportunity of being met through other input to which the subject was exposed in daily life. Therefore, contributing to a safe conclusion, 20% of 116 words had been learnt.

This reveals that even when highly frequent words were removed from this research, the findings still showed the significant incidental learning through reading, unlike some previous studies, which showed a small number of gains.

However, like every other study, this study had some limitations too. Firstly, the learning reported is based on self-reporting by the subject; secondly, the YES option in the test does not necessarily show that the subject knows the correct meaning of the word. It would be more reliable if the subject would write the synonym or meaning of the words she answered YES. Additionally, the researcher asked the participant to highlight the new words; she probably paid some degree of attention to the highlighted words, which could have affected the incidental acquisition status in this study. Also, the participant was allowed to look up a new word in a dictionary, so the learning reported cannot be ascribed to the incidental acquisition mode.

2.2.6. Factors that Employ in Vocabulary Learning

Although for L1 learners, it always seems that they profitably learn words through exposure to language input. Second language learners do not always enjoy this fact (Laufer, 2005b). Schmitt (2008) mentions that due to the insufficiency of vocabulary encounters, vocabulary acquisition from reading might be unsuccessful. Language learners may fail to notice unknown words; four components related to vocabulary acquisition are noticing, elaboration, meaning verification, and frequency of exposure.

In second language acquisition, these four components—noticing, elaboration, meaning verification, and frequency—are widely recognized as key cognitive processes that facilitate vocabulary growth. According to Nation (2013), noticing is essential because learners must first become aware of a new lexical item to process and eventually store it. Without noticing, incidental vocabulary learning is unlikely to occur, particularly when learners lack sufficient language proficiency or contextual support to infer meaning.

Elaboration, or the degree to which a learner processes and integrates new information, is another critical factor. As Ellis (1995) argues, deeper cognitive engagement with a word— such as through semantic mapping, personal associations, or contextual

analysis— enhances memory encoding. When learners mentally link new words to prior knowledge or create associations between word forms and meanings, they are more likely to retain and recall those items later.

Meaning verification refers to the learner's attempt to confirm the meaning of a word, either through context, dictionary use, or feedback. Learners who verify their understanding are more likely to develop accurate mental representations of vocabulary, thereby reducing the risk of fossilization or incorrect usage (Laufer & Hulstijn, 2001). Finally, frequency of exposure has consistently been shown to be crucial: a single encounter with a word rarely leads to acquisition, especially in L2 contexts. Research suggests that a minimum of 6–10 meaningful encounters may be needed for a word to be learned receptively, and even more for productive mastery (Webb, 2007).

In addition to these internal cognitive processes, external factors such as task type, input modality, and learner motivation also influence vocabulary acquisition. For instance, listening and reading provide different opportunities for noticing and elaboration (Brown, Waring, & Donkaewbua, 2008), and multimodal input (e.g., combining images, text, and sound) may enhance memory and engagement. Furthermore, motivated learners are more likely to notice and process new vocabulary intentionally, making affective variables an important consideration in instructional design.

Taken together, these factors suggest that successful vocabulary learning in a second language is far from automatic. It involves a combination of input quality, cognitive engagement, and instructional support. Teachers and materials developers can facilitate this process by designing tasks that encourage active noticing, repeated exposure, and meaningful elaboration, ultimately supporting learners in building a more robust mental lexicon.

2.2.6.1. Noticing

Many scholars agree on noticing as a central factor for language to be internalized (Hulstijn, 1989, as cited in Rosa & O'Neill, 1999; Schmidt, 1990, 1995, 2001; Van Patten, 1990, 1994), although the possibility of the occurrence of language learning without awareness is a controversial issue yet. In contrary to some researchers (e.g.,

Leow, 2001; Schmidt, 1995, 2001; Swain & Lapkin, 1995), which support the significance role of noticing; some other scholars (e.g., Curran & Keele, 1993, as cited in Rosa & O' Neill, 1999; Tomlin & Villa, 1994) believe that there is no relationship between learning and awareness. Although the concept of noticing does not have the same definition for all scholars, many believe that selective attention seems to play an important role in learning (Gass & Selinker, 2008; Robinson, 1995).

Regarding vocabulary acquisition, Wesche and Paribakht (2000) in their study illustrated that some degree of attention to lexical items is necessary for fruitful word acquisition (Gass, 1988, as cited in Wesche & Paribakht, 1999; Schmidt, 1993). They both mention learners' consciousness of unknown words while they are reading a passage. When learners' attention is drawn to unfamiliar words, they are driven to further process the new information (Rott, 2007; Rott & Williams, 2003). The more they notice the unfamiliar words, the more vocabulary they gain (Bowles, 2004; Yanguas, 2009). Learners who chose a passive approach to learn vocabulary as opposed to the former kind of learners are probably slow and unsuccessful learners (Schmidt, 2001). Making the unfamiliar words outstanding by input enhancement (Ko, 1995; Leow, 2001; Paribakht & Wesche, 1996; Sharwood Smith, 1993) is an effective way to attract learners' attention to input (words). According to Bowles (2004), input enhancement assists learners in seeing the target items. Although Laufer (2005b) believes that further processing in addition to being noticed is needed for the words to be acquired.

2. 2.6.2. Lexical Processing

When words are noticed, learners need to process them to reveal their meanings. Lexical information must be elaborated to be learned (Peters et al., 2009). Hulstijn (2001) mentions that the condition of information processing is associated to vocabulary retention. "Level of processing" is significant; the more profound the vocabularies are possessed, the better they are retained (Craik & Lockhart, 1972). Regarding the vocabulary learning, studies have shown those words whose meanings are guessed or inferred are likely to be recalled better. The reason is that when learners guess the meaning of the new words, they try harder to process lexical information at the deeper level. However, when a meaning of word is given to the learner and does

not let the learner to infer the meaning, effective learning does not have chance to occur (Hulstijn, 1992).

2.2.6.3. Meaning Verification

Finding the accurate meaning(s) of a word is a further key to effective vocabulary learning (Peters et al., 2009). Find out the correct meaning has two benefits: it inhibits incorrect meaning inferences, and it can foster correct meaning into learners' memory (Grace, 1998). Contextual clues have significant role to help learners to infer the word meaning (Zahar et al., 2001). Although some scholars (e.g., Zahar et al., 2001; Schouten-van Parreren, 1989) believe that rich contextual information led to better vocabulary learning, some other ones (e.g., Mondria & Wit-se Boer, 1991) claim that over redundant hints in the context might have negative effects on vocabulary learning. Because when contextual information is too informative, it might prevent learners to notice the unknown words, because they assume they already comprehend the message of the text (Laufer, 2005b; Nation & Coady, 1988). While learners cannot infer the meaning of unknown words if contextual clues are inadequate (Laufer, 2001). Also, learners need to have a certain level of language to be able to perceive the meaning of unknown words in context (Pulido, 2003).

2.2.6.4. Frequency of Exposure

Exposure is the number of occurrences of a word in a language, and when in experiment, it refers to the number of a particular word in the passage. As studies have been shown the more frequent words are, the easier it will be retrieved by learners. Also, frequency of exposure has a great role in incidental vocabulary learning (Huckin & Coady, 1999). The significance of frequency of exposure can be inferred from Krashen (1989), as well, since he believed incidentally vocabulary learning is possible to take place when there is enough comprehensible input.

2.3. Attention in Second Language Acquisition

2.3.1. Definition of Attention

Attention refers to the way people approach data in context. In fact, it describes the addition of definite input into people's minds' processing possessions or in other words it deals with the concentration of consciousness on a particular object. It is a cognitive process considered in the field of cognitive psychology.

There are diverse definitions of attention. Richards and Schmidt (2002) define attention as "the ability a person has to concentrate on some things while ignoring others" (p. 37). According to Swain and Suzuki (2008), "attention is a limited capacity system and is the process of selecting information for further processing, while awareness is the subjective experience of noticing" (p. 558). Robinson (2003) categorizes attention as the procedure that encodes language input, keeps it active in working and short-term memory, and retrieves it from long-term memory. Leowen and Reindrs (2011) believe that one of the significant features of attention is its limit, as working memory capacity is limited. They also mentioned that learning take place in the presence of attention. Although level of attention varies it plays a crucial role in process of learning.

2.3.2. Attention and SLA

Every human being exposed to the vast variety of input that learning whole is impossible,

Schmidt (1990, 1993a, 1993b, 1993c,) claims that in order to gain any particular aspect of L2 the learner must first notice it, that is, be conscious about that part of L2. The fundamental issue Schmidt talks about is how certain parts of the general input confronted by the learner are selected as intake for acquisition. After an extensive review of philosophical matters relating to the role consciousness and awareness in learning, He declares that for L2 input to be practical to the learner, to transform to intake, it must initially be detected and noticed. By noticing, Schmidt (1990) means awareness of input.

He also relates noticing to each learner's experience of learning and ability to report that. It appears that Schmidt consider awareness with attention as crucial issue to noticing. The result of a study by Schmidt and Frota's (1986) confirmed the basic role of noticing to SLA; the study was diary research. One important drawback of diary studies is spans of time as large as some weeks, however cognitive process of L2 input occurs in some seconds or less. So, one must observe some more supporting issues to conclude the significant role of attention in SLA.

According to (Tomlin & Villa, 1994), four influential notions of attention are noticeable in them. Firstly, the attention is limited. The capacity of human's mental resource is limited, since human's mind is not able to process the whole data, which receives at any time; only selected parts of data go beyond further processing (Anderson, 1983,1990; Kihlstrom, 1987). Second, it is the selection of specific data for further processing. Studies changed the focus from limited sensory input capacity to human limit in ability to carry out multiple tasks at the same time. Therefore, not only there is a limited capacity in human mind but also some information is selected to be processed by mind due to the limitations. Thirdly, attention may act for demanding processing that contradicted with autonomous processing. Having observed more closely to human attention system, Posner, and Snyder (1975) claim there is a distinction between automatic and controlled processes. That is, however, the human mind has processing restrictions, it can run two tasks alongside, if at least one is automatic, but it has problems running two attention- demanding tasks at the concurrently. The fourth is that attention is a matter of the control of information and action. This idea refers to mechanism of attention control; this is uttering the process by which data is controlled to specify whether it receives resources of attention or not.

As studies show the bond between attention and learning is recognized. Paying attention is essential for learners to be able to learn. (Al-Hejin, 2005; Schmidt, 2001; Schmidt, 2010). It has been for long time since the history of language learning and acquisition has existed, learning a language has been claimed to be unconscious or conscious process. Krashen (1982) considers no role for attention in the acquisition process; however, Schmidt's (1990, 1995) Noticing Hypothesis emphasizes that there is no learning without attention. In contrast to Krashen (1981)'s belief that only

subconscious processes can lead to successful L2 acquisition, Schmidt (1990) introduced the significance of the conscious mode of learning, assessing noticing as a vital and sufficient situation for L2 learning. As Schmidt (1995) claims, having awareness at the time of learning is a must, and it will contribute to the input of new linguistic features in the memory for further processing. In 2001, he came to the idea that noticing is a facilitator of L2 language and, and he accentuated the role of attention in adult language learning. As Schmidt claims that the level of awareness needed is not always verbalized, according to his claim, learning attention and level of awareness (i.e., noticing) are needed. Furthermore, Schmidt (1995) considered the two psychological concepts, which are attention and awareness, as isomorphic. William 2013 claims that in this theory, it is ignored that “attention and awareness can be dissociated” (p.51).

If we consider attention and awareness as if they are the same, some faults are going to come up, since, in terms of research design, attention is a continuous variable while awareness is a dichotomous variable. Additionally, two more theoretical positions should be kept in mind to realize a better understanding of the notion of noticing.

First, Tomlin and Vila (1994) proposed a more concentrated analysis of attention. a) alertness, b) orientation, and c) detection are three units of attention. Alertness refers to readiness to address incoming stimuli, orientation means the direction of attention resources to stimuli, and detection is the selective cognitive registration of stimuli. While Schmidt believed detection is the most important factor and the two former ones just help to detection, Robinson (1995)’s model explained noticing as “detection plus rehearsal in short-term memory, before encoding in long-term memory” (p. 296).

Robinson (2003) stated that attention, along with rehearsal in short-term memory change input to intake. He stated that learning is possible to take place even when a learner perceives the form without subjective awareness, but the amount of learning is very limited. Robinson (2003) mentioned three stages of processing in which attention plays a significant role: 1. Auditory/visual intake, 2. Decision making 3. Monitoring via sustained attention.

These phases match with “the selection of information, capacity of resources and effort needed to sustain information” (VatPatten, Williams, Rott & Overstreet, 2004, p.87). Robinson combined the two models (Tomlin and Villa & Schmidt models) of attention into one model, mentioning that detection occurs before noticing and noticing takes place at later stages. In other words, Robinson’s model recognizes Tomlin and Villa’s concept of detection in language learning but its influence on learning has been reduced by considering it at an earlier stage in the process of learning before Schmidt’s notion of noticing, which he has put at a later and more central stage of input processing (VatPatten, Williams, Rott & Overstreet, 2004).

2.3.3. Attention and Eye-Tracking in Second Language Research

In recent years, eye-tracking technology has become an increasingly valuable tool in second language acquisition research for measuring attention in real-time. Unlike traditional behavioral measures, eye-tracking allows researchers to capture moment-by-moment indicators of cognitive processing, such as fixations, saccades, and gaze duration. These measures can offer insights into how learners allocate attentional resources when encountering challenging language features, including phrasal verbs.

Recent advancements in second language acquisition research have increasingly adopted eye-tracking technology as a means of operationalizing and measuring attention in real time. Eye-tracking allows researchers to observe how learners allocate visual attention during language processing tasks, providing insights into the cognitive demands of different linguistic stimuli (Godfroid, 2020). Fixation duration, saccade length, and regression paths are considered reliable indicators of attentional allocation, which align with the theoretical frameworks proposed by Schmidt (1990) and Robinson (2003). In particular, eye-tracking data can serve as a proxy for noticing, especially in tasks where learners encounter unfamiliar vocabulary or complex multi-word expressions such as phrasal verbs. Phrasal verbs, due to their opacity and syntactic variability, are known to impose higher cognitive loads on L2 learners, which often translates into longer fixation times and increased rereading behaviors (Neufeld & Hacking, 2022). Studies have shown that visual attention— captured through first fixation duration and total fixation time—correlates closely with reaction time and comprehension accuracy in lexical decision tasks, highlighting the role of implicit

processing mechanisms (Conklin et al., 2023). Therefore, incorporating eyetracking into SLA research not only enhances the precision of data collection but also bridges the gap between theoretical constructs like noticing and their empirical measurement. In the context of the present study, eye-tracking was used to trace how advanced L2 learners respond to semantically related and unrelated phrasal verb primes, providing a nuanced picture of how attention influences lexical access and decision-making during reading.

2.4. Priming

2.4.1. What is Priming?

Having reviewed the related literature, it is conspicuous to follow the rate of the increasing role of psycholinguistics in applied linguistics. One frequent method in psycholinguistics is priming. Priming generally refers to a situation in which prior knowledge of a certain form or meaning in a language assists or interferes with learners' successful learning. Therefore, it is commonly used to investigate the effect of provided input on language production or comprehension (McDonough & Trofimovich, 2011). Priming methods are considered a prevailing experimental paradigm to study diverse dimensions of cognitive aspects of language learning. According to McDonough and Trofimovich (2011), priming occurs with little consciousness, and that is why it is assumed to be an implicit procedure and so connected to a larger system, which is named implicit memory. The term "priming" refers to all situations when specific prior knowledge of a form or meaning influences the subsequent learning of language. There are different types of priming (McDonough & Trofimovich, 2008).

As it is mentioned by McDonough & Trofimovich (2008), the first observation of priming dates to James Cattell (1860–1944), he is an American psychologist, and his time in Leipzig, Germany concurred with the time of the chronometric approach. "The chronometric approach relies on the use of reaction times (response latencies) to study various mental processes, including language comprehension and production" (McDonough & Trofimovich, 2011, p. 5).

Having investigated the speed of language production in L1 and L2, Cattell discovered that it takes a longer time for language users to read an unrelated sequence of words than related ones. The word “priming” apparently emerged in research by Feldman and Weld (1939), cited in McDonough and Trofimovich (2011), who mentioned “the state of attentional preparedness”; for instance, if a person is waiting for a call, she may hear the ring with a higher probability. Priming in language, as psycholinguists use now days first mentioned by Segal and Cofer, as cited in McDonough and Trofimovich (2011), who noticed in their study that when language learners are exposed to a set of words, they tend to use the same word in the coming task. It has been for several decades that all psycholinguistic studies that apply priming use computers to show stimuli (e.g., pictures, passages, voice, audio) and use software to estimate the participants’ reactions, including speed, duration, and latency to presented stimuli.

2.4.2. Types of Priming

Semantic priming occurs when language learners access the meaning of a word or utterance by connecting to some other words that are similar or have something in common with the word they have heard or seen. For instance, language users will get the meaning of nurse more rapidly when it is followed by a word such as doctor, as opposed to an unrelated word like book. In other word it is a tendency for speakers to process a word faster when they have encountered another word that is related to one they are processing. As an instance of different priming, if a speaker uses a preposition such as datives in German and the listener uses the same in his or her speech to respond under the influence of what s/he has heard. In bilingualism studies, semantic priming paradigms have been chiefly oriented towards cross-language rather than withinlanguage priming, since by observing crosslanguage priming, researchers can find out how two mental lexicons are organized (Jiang & Forster, 2001; Kroll & De Groot, 1997).

Studies that have focused on within-language priming have commonly drawn the conclusion that proficient bilinguals demonstrate higher acceleration with semantic priming (Favreau & Segalowitz, 1983). Semantic priming in most studies is an internally validated evaluation since researchers counterbalance the order of primes in

categories of related and unrelated prime-target pairs (Hutchison et al., 2013). One of the largest semantic priming databases came from a study by Hutchison et al., (2013) who collected data from 768 participants and investigated speeded naming and lexical decision data for 1661 target words. This data is available for other researchers to use.

Syntactic priming, as it is expressed by its name, relates to the structure that has an impact on language production. For instance, Perdomo (2017) in their research investigated congruent and incongruent phrasal verbs, and as a result, they concluded that whenever in the examples and questions separable phrasal verbs were used, the participants used the same structure. (Zhou, 2020). A review article on structural priming claimed that structural priming has a vital role in both acquiring L1 and learning L2. In other words, syntactic priming refers to a tendency to select any structure that was seen in the recent confrontation with the language. It is also named structural priming (see Dell and Ferreira 2016 for review). Many scholars applied structural priming in their linguistic research in different areas, including actives and passives (e.g., Kim & McDonough 2008), alternation between two structures in an L2 learner's interlanguage (e.g., McDonough & Kim 2009; McDonough & Mackey 2008), and syntactic ambiguity (Havron et al., 2020), syntactic priming and its effects in production and comprehension (e.g., Bock (1986); Tooley & Traxler, 2010), word order in a second language (e.g., Jackson & Ruf, 2017); structural priming and switching in bilingual conversation English-Spanish (e.g., Fricke & Kootstra, 2016). They found that structural priming also applies to real life bilinguals' code-switching conversations.

According to Weber et al. (2019), structural priming can lead to implicit learning. In his study, they investigated the first days of L2 learning since they theorized syntactic structure of repetition helps the form-function mapping. They also found that different factors, such as structure occurrence and lexical data, affect syntactic priming. The priming effect needs to have more power for infrequent structures because novel structures contribute to a larger error signal (Ferreira & Bock, 2006).

Auditory priming occurs when the speaker hears a particular word from an interlocutor and tends to process it more easily and more accurately when it is used again in the

same conversation. Some studies investigated the comparison between audiovisual semantic priming and audio semantic priming in recalling the L2 vocabulary.

2.4.2.1. Semantic Priming Models

Table 2 provides an overview of major semantic priming models discussed in the psycholinguistic literature. The models differ in their assumptions about the organization of the mental lexicon and mechanisms of lexical activation. These accounts provide the theoretical background for interpreting priming effects observed in lexical decision and eye-tracking studies.

Table 2 Semantic Priming Models (McNamara, 2005)

Semantic priming Models	Dates Back	Who	Idea
Spreading Activation Model	1967	Quillian	Memory is assumed to be a network of nodes intersected by links. The nodes signify concepts and links depict the relations among concepts.
Collins and Lotus Model	1975	Collins and Lotus	Distinguishes the meaning of concepts from knowledge of their names
ACT model	1976,1983	Anderson	
Becker's Verification Model	1976, 1979, 1980, 1985	Becker	Visually showed words stored in visually sensory memory Strategic Procedures
Compound-Cue Models	1988	Radcliff and McKoon	The cue to memory includes target items and other elements, such as prime.
	1989	Dosher and Rosedale	
Distributed Network Models			
Multistage Activation Models			
Logogen-based models	1969	Morton	There are a mentally feature counters to represent words
Interactive-activation model	1981	McClelland and Rumelhart	
Forster's Models	1999	Forster	Different types of form priming
Norris's Context-Checking Model	1995	Norris	The more frequent a word is, the sooner it will be recognized

Neely and Keefe's Hybrid model	1989	Neely and Keefe	
ROUSE (responding optimally with unknown sources of evidence)	2001	Huber, Shiffrin, Lyle, and Ruys	Some biases in decision making which may be automatic seems to affect

2.4.2.2. Masked Priming

Whether semantic processing of written words is automatic is a controversial dispute: some scholars argue that semantic processing of word meaning arises without cautious attention and it is undeliberate (Greenwald et al.,1996; Kiefer and Spitzer,2000; Kiefer, 2007; Kiefer and Martens,2010). Some other researchers discuss that processing the meaning of words needs perception of words (Duscherer and Holender, 2002). One other insight in favor of the automaticity of semantic priming is rooted in the concept of masked semantic priming research, in which the prime is subliminally offered. Semantic priming is commonly investigated through the Lexical Decision Task (LDT) in which participants are required to decide whether a word they see is a real word or a non-word; reaction times are faster if the target is preceded by a semantically related prime. Reaction Time (RT) difference between related and unrelated primes is named the semantic priming effect. In masked priming studies, primes are preceded by a string of unrelated letters or symbols before presenting the target. When a masked prime word smooths the processing of the target stimulus (word), unconscious semantic activation is presented. Having reviewed related literature, many scholars applied “masked priming” in their study, as it is used in my thesis, as well. Masked priming is usually used when researchers aim to find out participants’ sensitivity implicitly in an online lexical decision task (e.g., Rastle & Davis, 2003).

It is worth briefly mentioning that the pioneers of using masked priming in visual word recognition are Forster and Davis (1984), with theses phases a mask (usually symbols like ####) for 500 ms, a prime which is appeared for about 50 ms which is headed with the target and feedback (response) is required here commonly in lexical decision task. Response can be prolonged 500 ms, or if participants react and respond. Kinoshita and Norris (2012) claimed that the selection of a task may influence the priming effect; for

instance, priming effect can occur for non-words, or they might become faded for words (Norris and Kinoshita, 2008).

Having scrutinized the conception of masked priming in literature this question arises whether presenting something unconsciously can have an impact on behavior? This intriguing question was debatable and still disputable (e.g., Merikle & Daneman, 1998; Sidis, 1898). In psychology, one of the earliest studies on the probable effect of presenting stimuli subliminally was first carried out by Sidis (1898). It is worth mentioning that since then, up to now, this is the matter of debate (for review see Kouider & Dehaene, 2007). Van den Bussche et al. (2009), in a meta-analysis of masked priming, examined the related literature to discover strong support for the semantic processing of subliminal stimuli by assessing the effect size of subliminal priming.

Their study focused on unconscious priming in which the prime is masked and invisible.

Another study by Eckstein and Perrig (2007) focused on the impact of intention on masked priming by using a set of words that were semantically classified. They applied masked priming in their studies using the short prime-target intervals. One feature of short-lived priming it presents immediately at prime- target breaks stimulus onset asynchronies (SOAs) longer than 100 ms (e.g., Naccache et al., 2002), which are shorter than the usual intervals 200-500 ms that are commonly used in classical masked priming studies (e.g., Greenwald et al., 1989). They designed the decision task adapted from Klinger et al. (2000) in which a group of subjects did a positive/negative word classification task (e.g., heaven vs. hell) and the other group went through an animate/non-animate (e.g., baby vs. heaven) decision task for the same set of words. Eckstein and Perrig (2007) viewed faster response when prime and targets were congruent; their result also demonstrated that the intention of reacting to valency or animacy affected the way primes were processed.

In a nutshell, masked priming is defined as a kind of visual priming which is based on visual stimulation and the term masked signifies the use of symbols “#####” presented before or after the prime. It is commonly used as a powerful strategy in different priming studies to eliminate or decrease the effect of previous stimuli or upcoming ones (Elgendi et al., 2018). Another intriguing term used in priming or masked priming paradigms, especially a short-lived one, is named “subliminal priming,” which occurs when primes

appeared less than approximately 500 ms. This is below the threshold of perception as it is displayed in Figure 1. In subliminal prime, participants are unaware of seeing primes since they appeared and disappeared rapidly, and it is below conscious recognition (Lorenzo et al. 2016), but their decisions are still influenced by primes. Subliminal priming has been widely used in different psychological research, marketing, cognitive research and the results are used for social health, human-computer interactions, marketing and even political campaigns which is normally examined by EEGs and Eye tracking, which both will be defined later in this chapter; therefore attracting enough to be applied by psycholinguists, researchers of cognitive science of language learning and linguists who found the implicit processing of language appealing.

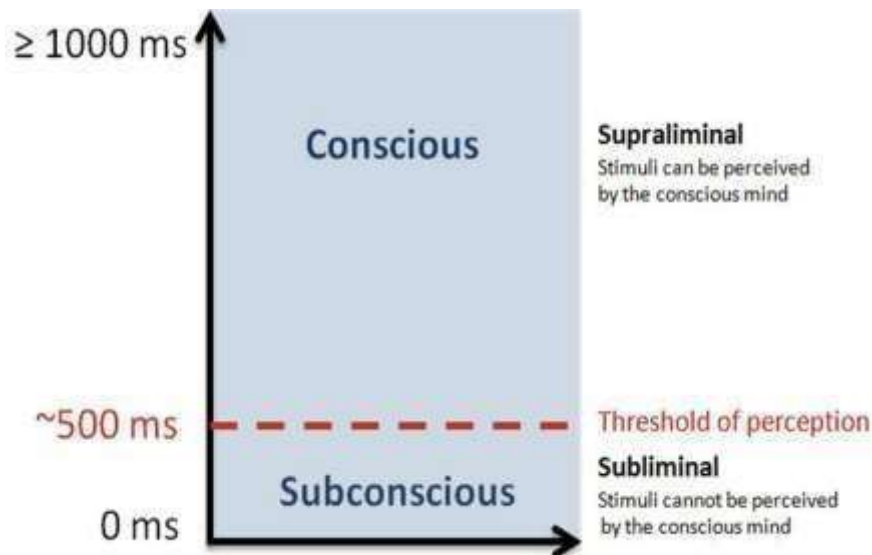


Figure 1. A visual graph of supraliminal vs. subliminal priming adapted from (Elgendi et al., 2018).

2.4.3. Priming Methods and L2 Learning

2.4.3.1 Lexical decision task

As in the previous part, it is stated that semantic priming deals with the meaning. To examine semantic priming Lexical decision task (LDT) is the classical task that is well known. In this task, stimuli consist of a correct word and meaningless strings of letters. Participants attend the experiment session and, in each trial, both word and nonword appeared on a computer screen; participants decide whether the strings they have seen were a word or a non-word. Both within-subject and between-subject studies can benefit from LDT. The major measurement in LDT is the speed of answers, which shows the

probable effect of the prime, which has been demonstrated in front of the subjects, which can be pictures or words. The speed at which participants respond to the stimulus, which is a word or not, is called reaction time (RT), which is an essential factor in lexical decision tasks. To put it in other words, semantic priming refers to facilitation, which LDT is reflected in faster reaction times.

Three diverse aspects contribute to effective vocabulary learning: attention, imagination, and connecting the new information one wants to learn to some knowledge one already has. Attention is vital, since unattended information does not have a great opportunity to remain in the memory to be retrieved later. Imagination is a great assistance in retaining the information, especially for concrete words. For instance, the word "cat" can be learned more easily when connected to a picture of a cat (Altarriba & Bauer, 2004). Linking new information to previously learned information increases the probability of retention of the new information, as well, which priming suitably attempts to investigate this aspect. Kumar et al., (2017) used lexical naming tasks for children of 5 and 6 years old to elicit the reaction time to prepare reaction time measurement paradigm; 10 boys and 10 girls participated in this research, they went through two conditions of no prime (no auditory stimuli presented before onset the picture) and prime (word which is semantically primed with the picture is played 700 ms before onset of the picture) Children were required to name the pictures in these two different conditions. Results depicted a faster speech reaction time when semantically related audio had been offered before presentation of the target (picture). Kumar et al., (2017) concluded that the primed condition accelerated lexical retrieval for the children. A study by Dezfoulan et al. (2015) used three types of audio presentations, visual presentations, and a combination of both (audiovisual presentations) in their study to observe probable differences. 46 undergraduate students took part in the study. They claimed that both audio and audio-visual priming had a greater effect on vocabulary retention. They have also observed quicker performance from students who went through audio stimuli or audio-visual stimuli rather than those who were exposed to visual semantic priming.

There are two kinds of perceptual and conceptual priming. In perceptual priming, the prime has physical features of the target, and it is form-related, while in conceptual priming, the prime has some meaning properties of the target (see, e.g., Blaxton 1989).

It can happen during L1 to L2 translation, as Barcroft et al., (2002) demonstrated by their English-Spanish study by using dad as a keyboard for dado “dice” and using an unrelated word book for dado “dice” to figure out whether using keyword methodology facilitate vocabulary learning process.

2.4.3.2. Semantic priming and word learning

As it is mentioned in the previous part, priming is a good method in a paradigm such as LDT to probe how new vocabulary is linked to the learned ones. When participants must decide whether the words they are seeing are a word or a non-word, which is preceded by a rapid presentation of another word or part of a related word, which is called a prime. So sometimes prime and target are semantically related (e.g., nurse and doctor), and sometimes unrelated (e.g., wall and doctor). This phenomenon is interesting because it is unconscious for a person since the prime is presented briefly. Neely (1977) in his research demonstrated that the priming effect can occur if the interval between prime and target is long enough, for example, if the participants see the word black, they may be able to predict the word white as the target. In fact, when a prime is presented for a short time, which is subliminally and is not perceived consciously, semantic priming would occur automatically (Marcel, 1983).

There is a widespread belief that the process which takes place during automatic semantic priming effects that the words around the semantic network become activated (Collins & Loftus, 1975). According to this attitude, words are like some nodes in a lexical network, and they are wired with other matching semantic nodes. When a prime word is noticed, the lexical node connected to that word will be activated, and then these nodes pass the activation to other semantic nodes that are in the same network. The idea assumes that if one of these lexical nodes appears as a target, its recognition would be accelerated since it is represented by the related node of the semantic network, which is presented in the prime. Semantic priming has often been applied in learning L2 vocabulary learning to investigate the cross-linguistic effects. For instance, if for a Spanish learner of English, perro primes dog (L1-L2) or dog primes perro (L2-L1 priming), if this occurs, it could result in L1 and L2 words being connected according

to their meaning to the same semantic networks (for a review, see Altarriba & Basnight Brown, 2007).

Studies show this as an example of automatic priming for L2 proficient speakers, when primes are demonstrated very momentarily (Keatley, Spinks & de Gelder, 1994; Tzelgov & Eben-ezra, 1992) when the primes are presented subliminally, for a very brief time that they cannot remember their perception (Perea, Dunabeitia & Carreiras, 2008). As studies show at a very high proficiency level, semantic priming effects from L1 and L2 are equal. So, translation priming seems to be weaker from a second language to a first one in comparison to L1 to L2.

Although according to Posner and Snyder (1975), semantic priming is assumed to be a relative measure since one cannot assure whether related primes soothe the performance or, on the other way unrelated primes hinder performance. To ascertain soothing or hindering effects of related and unrelated primes, some “neutral” priming conditions as a baseline are vital in the task; these neutral priming contained a string of Xs. The first scholar who applied neutral prime in his research was Neely (1976), who discovered general priming effects of 54 ms (unrelated-related) contained 38 ms facilitatory effect(neutral-related) and a 16 ms inhibitory effect (neutral-unrelated). There might be a downside of Neely’s neutral prime that a row of Xs cannot be considered as meaningful words, and they may not involve a linguistic system similar to the way it happens in word prime (McNamara, 2005). Also, there are shortcomings for repetition priming, such as decreasing the needed time to instruct neutral priming and likely losing qualities as the experiment proceeds.

In addition to areas that have been mentioned above, semantic priming has been investigated in novel word learning. Tamminen and Gaskell (2013) depicted in their study that semantic priming can be used as an indicator for lexical integration based on semantic relatedness or semantic associations (e.g., Hutchison, 2003; Lucas, 2000). Association refers to the situation that two words are linked together because of cooccurrence (e.g., mouse and cheese); on the other hand, relatedness refers to two words that overlap some features (e.g., cherry and apple). They also stated one other situation in which semantic priming can arise in the case of mediated or indirect semantic priming (see Jones, 2010, for review). It suggests that processing of the target

(e.g., cheese) is accelerated by a semantically indirect prime (e.g., cat) that is linked indirectly to a mediator (e.g., mouse).

As Dagenbach et. al., (1990) demonstrated in their study, episodic semantic priming happened in learning obscure words. They set “drupe” (which is a fleshy fruit with a hard stone) followed by an episodic list, which paired newly acquired words with semantically related words (e.g., drupe-cherry). Perfetti et.al., (2005) instructed 60 opaque words over forty five-minute teaching session to participants including repeating the words and their meanings. This session was directly followed by a test session which subjects were going to do a semantic decision task while event-related potentials (ERP) were recorded, and faster reaction times (RTs) were reported for related than unrelated trials. There are some more instances of finding semantic priming in learning new words in the following part which ERP is explained.

2.4.3.3. Semantic Priming and Phrasal Verb

According to the literature, structural priming has been more frequently investigated than semantic priming in the context of phrasal verb processing (for review, see Perdomo, 2017). In her thesis, Perdomo (2017) focused on continuous and discontinuous phrasal verbs. For instance, in her task design, participants were shown a prime sentence containing a discontinuous phrasal verb (e.g., she got the ball back). Then, they were asked to construct a sentence using a set of provided words (e.g., out, trash, threw). Most participants produced a sentence with a discontinuous structure, such as she threw the trash out, showing clear structural priming effects. This finding supports the idea that exposure to certain syntactic patterns can influence subsequent production, particularly for verb-particle constructions.

While structural priming has been central, many scholars have also explored semantic association and lexical priming in the processing of multiword expressions. Hoey (2012) emphasized how repeated exposure to word combinations strengthens associative links in memory, which can affect comprehension fluency. Similarly, Ke (2013) reviewed work on semantic sequencing and lexical co-occurrence, noting that learners internalize meaning relationships through patterned exposure. These

perspectives have shaped the understanding of how learners build sensitivity to phrasal verbs over time.

A key concept in this area is semantic transparency—the extent to which the meanings of individual components in a multiword expression contribute to the overall meaning. For compound words, Juhasz (2018) defined semantic transparency as the degree to which constituents meaningfully relate to the whole. Transparent compounds such as *milkman* are easier to process because their meaning is predictable from their parts, unlike opaque ones like *honeymoon*. Sandra (1990) showed that transparent compounds elicit stronger semantic priming effects. Likewise, Libben et al. (2003) reported faster reaction times for transparent compounds like *bedroom* compared to opaque items in lexical decision tasks. However, results are not always consistent—Juhasz (2007, 2018) found semantic effects on gaze duration but not on fixation duration in compound word reading.

In a large-scale study, Kim et al. (2019) examined 2,861 English compound words and provided semantic transparency ratings based on participant judgments. They used visual word recognition, lexical decision, and pronunciation tasks with over 250 participants. Each subject rated word pairs on a 7-point semantic similarity scale, offering valuable insights into how constituent transparency shapes lexical access. These data help bridge semantic priming research with compound word recognition, offering parallels for understanding phrasal verbs.

As discussed earlier, the status of phrasal verbs remains debated. Some linguists, such as Jackendoff (1995), argue that phrasal verbs function as single lexical units, with meanings often stored holistically, especially for opaque combinations. This view implies that learners may process them as unanalyzable chunks, bypassing the individual meanings of verb and particle. However, others emphasize the compositional nature of many phrasal verbs, particularly those with transparent meanings.

In line with this, Blais and Gonnerman (2012) conducted a masked priming study to examine bilinguals' sensitivity to semantic transparency. They tested French-English bilinguals on phrasal verbs varying in transparency (e.g., *chew out*, *finish up*), using both explicit similarity ratings and an implicit lexical decision task. Results showed that

bilinguals processed transparent phrasal verbs more efficiently and demonstrated comparable priming effects to native speakers, suggesting that semantic transparency facilitates L2 acquisition of verb-particle constructions.

Recent research continues to explore the interaction between semantic priming and word predictability in phrasal verbs. For instance, Tiv et al. (2019) examined semantic similarity between phrasal verbs and their base verbs (e.g., carry vs. carry out) and found that strong semantic overlap led to faster response times, particularly among advanced L2 learners. Zhang and Wen (2019) also emphasized the role of conceptual metaphors in interpreting opaque phrasal verbs, proposing that learners can leverage metaphorical associations to grasp idiomatic meanings.

Additionally, a study by Guo and Park (2023) used eye-tracking to compare the reading of semantically transparent versus opaque phrasal verbs in L2 learners. Their results showed that transparent combinations led to shorter first fixation durations and total reading times, especially in high-proficiency learners, indicating that semantic priming supports more efficient visual processing. Similarly, Meunier and Longtin (2021) demonstrated that priming effects in masked lexical decision tasks were stronger for high-frequency and transparent phrasal verbs, further reinforcing the connection between semantic access and form familiarity.

Neurolinguistic evidence also supports semantic sensitivity in phrasal verb processing. Cappelle et al. (2010), using magnetoencephalography (MEG), found greater neural mismatch responses for incongruent pairs like heat down compared to congruent ones like heat up, suggesting the brain detects violations in learned semantic patterns. These findings align with models proposing a gradient of semantic compositionality, rather than a binary division between transparent and opaque phrasal verbs.

In conclusion, while structural priming remains central to understanding phrasal verb processing, semantic priming plays a crucial role in shaping both implicit and explicit learning pathways. Transparent phrasal verbs benefit from faster processing, both behaviorally and neurologically, while opaque forms may require holistic retrieval. For L2 learners, increased exposure, familiarity, and metaphorical awareness seem to enhance sensitivity to phrasal verb meanings, as supported by both behavioral and

eyetracking studies (e.g., Guo & Park, 2023; Tiv et al., 2019). Future research may further clarify how semantic priming interacts with syntactic familiarity and frequency to shape the dynamic processing of these multiword units.

2.4.3.4. EEG, fMRI, and Semantic Priming

ERP (event-related brain potential)

In electroencephalography (EEG), brain electrical activities, which are produced by neurons, are recorded. What is ERP? Event-related brain potentials are EEG responses that are time-locked to a specific stimulus. One of the benefits of ERP is its high temporal resolution. ERP measures are a kind of direct echo of the brain activity (Kutas & Van Petten, 1994). According to Van Petten and Kutas (1991), while ERPs are recorded, they plotted some negative and positive peaks. Some of the ERP components have been recorded in psycholinguistics literature, such as LAN, N100, P200, P300, N400, and P600. In the following part N400 is briefly explained. The N400 is a wave that appears between 300 ms and 500 ms after stimulus onset. N400 is sensitive toward semantic violation; It was first explained by Kutas and Hillyard (1980). ERPs elicited by a semantically congruent sentence (e.g., Mary eats pizza) in comparison to a semantically incongruent sentence (e.g., Mary eats window), the violation to N400 happens in the latter situation. N400 is also influenced by predictability and frequency of stimuli; in less frequent and less predictable words, bigger N400 amplitudes would appear (for review, N400 and semantic priming, see Bakker et al., 2015; Steinhauer, 2014). One of the other components is P600, which refers to morphosyntactic processing; it is sensitive to grammatical errors (e.g., Mary eats cake vs. Children eats cake), which occurs 600 ms after the onset of stimuli. Figure 2 illustrates the N400 effect.

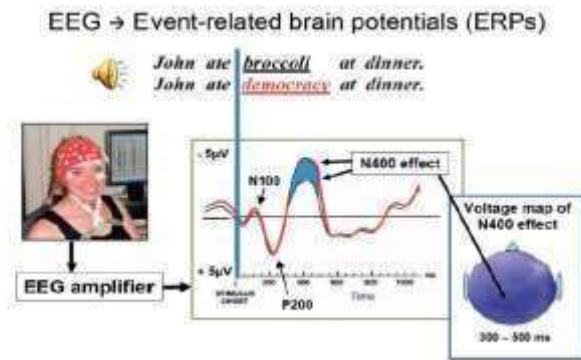


Figure 2 Voltage map for N400 in EEG setting adapted from Steinhauer (2014). N400 effect can be seen for target words of broccoli vs. democracy.

The first studies that applied ERP with multiple words date to 1993 by Strandberg and his colleagues; they investigated the processing of figurative phrases versus corresponding novel phrases by autistic patients. Researchers recorded ERPs on the final meaningful figurative and non-figurative words (e.g., idiomatic: vicious circle vs. Literal vicious dog). They have depicted that a smaller N400 was presented for the most frequent figurative words compared with literal ones. Vaspignani et al. (2010) drew the same conclusion by observing a smaller N400 for Italian idiomatic phrases than for literal ones.

Online measurement of language processing is a remarkable method that has found its way to psycholinguistics and the cognitive science of language. Eye-movement tracking, event-related brain potential (ERP), which reflects voltage changes in electrical brain activity in response to a stimulus. It can be elicited from the electroencephalogram (EEG) via signal averaging. fMRI is popular among scholars, as well. In different studies, while participants are carrying out lexical decision tasks or semantic tasks EEG is being recorded. Some studies focused on semantic priming by applying ERP (e.g., Khader et al., 2003). In research where fMRI has been used, subjects go through fMRI while they are doing tasks (e.g., Bick et al., 2010). Eye movement can demonstrate the gaze duration and regressive eye movements. ERP measures the brain activity while doing the task.

In a study by Phillips et al. (2004), bilinguals (English L1, French L2) took part in two experiments designed to investigate individual differences using both behavioural measures and event-related potentials (ERPs). In the first experiment, 37 participants

made living/non-living judgments of English and French words. Response times were measured for both related prime–target pairs (e.g., adult–child) and unrelated pairs (e.g., rabbit–child). The results showed that participants responded more quickly in L1 than in L2, particularly when making semantic (living/non-living) judgments to related prime–target pairs. In Experiment 2, Phillips and his colleagues obtained the same pattern of results with 29 participants, this time using measures of electrical brain activity, specifically the N400 ERP component. A mixture of these two methods provides good data about automaticity and cognitive processing. Some other ERP research has concentrated on L1/L2 interference in bilinguals. Addressing implicit activation of L1, as it has been shown by Thierry and Wu (2004, 2007), late bilinguals of Chinese/English instinctively turn English words into their Chinese counterparts.

Another stunning research by Martin et al. (2009) explored semantic priming in both ‘active’ and ‘non-attended’ language in highly proficient bilinguals. They scrutinized brain potentials in these two groups. Twenty Welsh/English bilinguals went through the task which contained 156 English words and 156 Welsh words (with the same meanings) divided into two groups of 78 primes and 78 targets in eight blocks; subjects were instructed disregarding Welsh word, counting the letters of English words and they had to press one button if the letters were less than five and the other button when the letters are more than five. In experiment 2, subjects were asked to do the same for Welsh words, counts letters of Welsh words, and not English words. They showed that spontaneous semantic and lexical access existed in both languages during the first 400 ms after the presentation of a stimulus (a word).

De Grauwe et al. (2014) in their study used fMRI to investigate long-lag priming in two groups of native speakers of Dutch and late learners of Dutch whose L1 was German. They applied a long-lag methodology in their investigation, according to which, in one condition, targets (complex transparent verbs) were headed by primes (their stems), and in the other condition, the stems were primes. The subjects saw 140 words containing 35 primed complex targets, 35 unprimed complex targets, 35 related stems as primes, and 35 unrelated ones as fillers; 28 pseudo-words were also added. When participants were lying in the scanner, stimuli were presented through a mirror placed on the head coil. They were asked to press a button on a response box with their right index finger to pseudo-words only (go/no-go task). The sequence of stimuli in each trial was a blank

screen for 0 to 2000ms, then a fixation cross (400ms), followed by the stimulus, which remained for 2000 ms or until the subjects pushed the response button. At last, a blank screen appeared until the fixed trial length of 8440 ms. Participants saw all 196 trials in one block, which took 30 minutes.

2.5. Eye Tracking Method

2.5.1. Online methodologies in language processing research

Online methodologies have become popular among linguists and psycholinguists, unlike offline methods like pretest-post-test which assess the moments before and after the time language is processed, or for example sentence-picture matching task in sentence comprehension experience. One important characteristic of offline measurement, for instance, since the questions are asked after showing pictures, the role of working memory is crucially important because they have to keep the sentence which they read in their working memory to be able to process that after reading the sentence better to say they process the sentence at the time of reading it but they have to keep it in their mind and when they see the matched picture they can choose it. Therefore, subjects with better working memory outperform in this task. As Marinis (2010) mentioned other limitation of off-line measurements refers to the time that subjects have to think about the sentence before they are asked to see the picture and select the matched ones. Consequently, they use their explicit knowledge and make a conscious decision about the meaning of the sentence. Almost every method assessing language processing from 1990 was offline, for instance, sentence-picture matching, grammar judgement tasks, picture description (See Mackey & Gass, 2016, for a review).

On the other hand, in online measurements current behaviour of a person while exposed to the language is being scrutinized. Depending on the task, the subjects went through online measurements of their automatic and unconscious response to language stimuli. Designing online measurements takes more time since they are more complicated than offline tasks. Additionally, analysing data that is collected from online experiments is more complex and time-consuming compared to offline tasks.

Reaction times are key term in online language measurement, if in an experiment, words are going to be studied on, participants hear a word or see a picture of a word (e.g., tree), then they listen to a sentence that may or may not include the words they heard before; participants are required to press a button if they heard the words before as fast as they can and their reaction times are being recorded by computer. RTs in milliseconds demonstrate how fast subjects reacted to the stimuli by pressing the button, for example. Correct answers are calculated as a percentage in each condition.

The think-aloud method is when participants say the things they think while they are doing the task. It can be used to examine cognitive processes as they are revealed during some activities, such as language processing. Think-aloud provides qualitative result and it makes it outstanding among other concurrent online data collection methods.

Although it can be applied with other types of quantitative measurement (e.g., EEG). Regarding Second Language Acquisition (SLA), studies probing questions concerning noticing and awareness have benefited from the think-aloud method (Godfroid & Spino, 2015; Leow, 2000; Rosa & Leow, 2004; Rosa & O'Neill, 1999), strategy use in vocabulary acquisition (Fukkink, 2005; Nassaji, 2003). It is commonly believed that think-aloud indicates the contents of the speaker's short-term memory, which are claimed to be conscious (Ericsson & Simon, 1993). Consequently, unlike other online measurement methods, which can measure unconscious processing, as well, think-aloud principally measures conscious processes Godfroid, Boers, & Housen (2013).

Research by Leow et al. (2014) applied three methods of think-aloud, eye tracking and RT (reaction time recording) to study the early stages of L2 learning. From these three methods, they claimed that think-aloud was the only one that could distinguish between conscious and depth of processing. They have also found some features in common between RT and eye tracking, reaction time is easier to apply, and it is an economic method compared to eye movement data collection. Think aloud can be considered like self-paced reading in this feature that in both methods, subjects are asked whether to say something or press the button, but in eye tracking or ERP, participants are commonly asked just to read something, and their eye movements or brain voltage are being recorded without needing them to do a secondary task.

Self-paced reading (SPR) is another paradigm that is classified as an online measurement of language processing. Participants read or listen to sentences at their

own speed, and they press the button after each word or after each sentence according to what the task asks them to do. Their pressing button is being recorded, and longer RTs can show the slower processing due to difficulty or ungrammaticality of the sentence (Just, Carpenter & Wooley, 1982). Another paradigm stated by Marinis (2010) is cross-modal priming, in which subjects go through a dual task, and they must carry out two different tasks during the same procedure. For instance, in these kinds of tasks, students must decide by choosing a word or picture on the screen while they listen to a sentence. When they see the related picture or word, they must name it or press the button as fast as possible; their button-pressing time is recorded to elicit RTs. Researchers have used various versions of the SPR paradigm during 40 years of its existence, including centered or linear text presentation or cumulative or noncumulative format (Godfroid, 2020).

Eye-tracking is another online method that will be explained and defined more in this chapter. It is eye movement recording while a person is reading something on the PC screen, although not necessarily applied for reading, in marketing, for example, there are some mobile eye trackers which record participants' eye movements while they are shopping, for example. The interest in eye movement recording dates to the 18th century (Wade & Tatler, 2011). As it is cited in Godfroid (2020), William Charles Wells was a pioneer in eye movement research, and he discovered some valuable insights about eye movements, but unfortunately, his findings were mainly neglected, and some scholars rediscovered the same perceptions in the late 1800 which William achieved a century before (Wade & Tatler, 2005).

According to Rayner (1998), there are three waves of eye-movement research: early work (1898-1920) on the fundamentals of eye movements; the behaviourist era (1930-1958) described as the time when studies concentrated more on the applied area; and present eye movement research (mid-1970s-present), introduced by the arrival of computers. Scene perception, visual search, and language processing are categorized as three main parts of eye-tracking research (Rayner, 1998, 2009). It is worth mentioning that eye movement recordings are informative in many areas such as cognitive health, some psychiatric disorders, driving, marketing, and advertising (see Duchowski, 2007, for review). Eye tracking methodology and some research on language processing by applying this method will be comprehensively described in the next part.

Event-related potentials (ERP), as has been explained in the previous part is another online measurement. Unlike think-aloud, self-paced reading, and eye tracking, which are behavioral, ERP is a brain-based method that records waves of the brain by using electrodes that are directly put on the scalp. EEG is the raw recording of electrical brain activity, which is continuous, and when the collected signals are time-locked according to a presented stimulus, which can be an ungrammatical or unexpected word, it is called ERP. In language processing research, as it has been described in previous parts, brain activity is being recorded while participants are reading or listening to a sentence or a passage (see previous part, EEG and semantic priming). Researchers in ERP focused on 300-500 milliseconds and 600 to 900 milliseconds after the onset of the stimuli, which means the effect of ungrammatical or unfamiliar target show themselves in this range of time. ERP provides temporal information, the same as eye-tracking. The strength point of ERP in comparison with eye-tracking is that it can also provide evidence on whether ongoing processing are lexical-semantic or syntactic (Foucart & Frenck-Mestre, 2012).

2.5.2. What is eye tracking?

Eye-tracking is the recording of movements of the eye while the eyes are reading something on the PC screen. The reason it has drawn the attention of scholars is that they believe they can access cognition by eye movement recording. It is particularly said that eye gaze can demonstrate the cognitive process that occurs during a task, which can be reading, listening, or looking at a scene or object. It goes back to the idea of “eye mind link” (Pollatsek, Reichle, & Rayner, 2006, p. 4). What this theory refers to is that whenever the eye is looking at something, the mind is processing that. It is assumed that eye movement is linked with attention (Wright & Ward, 2008). According to this assumption, overt and covert attention draw attention of scholars; overt attention is the spot which the eye lands and gaze point occurs, covert attention which is mental focus is deeply associated with cognitive processing which is the reason of when and where the eye looks, for instance during reading (Godfroid, Boers, et al., 2013; Rayner, 2009; Rayner et al., 1989).

Overt attention is observable behavior that can be recorded while an observer is doing a visual task, although most linguists are more interested in what happens in the mind simultaneously. Can one say that overt attention and covert attention are related? This

salient question was stated in Godfroid (2020), and to address that, she mentioned Posner and his colleagues' location cuing paradigm, in which they asked participants shift their attention without moving their eyes. They must keep their eye gaze on the mark in the center of the screen, which is very challenging because people are naturally inclined to look at what they are paying attention to, and this is a natural tendency of people land their eyes where they are attending. With some practice and instructions, subjects could carry out the task. Therefore, they could isolate their covert orienting, and attention moved to the periphery, but their overt orienting (their eyes) kept focusing on the center of the screen. So, this research shows that when eye gaze is landed and fixed on a place, the attentional focus can turn to another part of the visual field (Styles, 2006). However, according to (Wright & Ward, 2008), severing covert and overt attention during visual perception demands much effort for everyone. It is worth mentioning that disjointing covert and overt attention is possible by attempting in very uncomplicated cognitive tasks, for instance, cue detection but it is more difficult in more complex tasks, for example, reading (Rayner, 1998, 2009).

In a nutshell, applied eye-tracking investigators examine overt orienting to find out more about covert orienting, which is an attentional process, because they mostly believe that overt and covert attention correspond. Eye-tracking scholars are attracted to investigating processes as it occurs. Eye movements are being recorded via infrared light; infrared mirrored onto the cornea, and follows eye movements on a PC screen with the help of a micro camera. There is a corresponding eye tracking software for each eye tracker, which helps to record and register the eye movements.

2.5.3. What features of eye movement do researchers measure in research?

Humans' visual field is limited, although one may assume they can see everything around them. We do not have sharp vision on everything around us; the area that can be perceived with high precision of vision is constrained to a small region around the sight line. There are three practical areas in the visual field: the fovea, the parafovea, and the periphery (see Figure 3). Fovea is less than 2 degrees of central vision, a tiny area in the center of the retina which has the highest degree of visual acuity (Rayner et al., 2012). When light reflected from the object or word, falls exactly and directly on the fovea, sharp vision occurs (Zhu & Ji, 2007). Therefore, the human vision has a limitation of

acuity, and that is why people make eye movements to see objects precisely, since by moving their eyes, people readjust the fovea with the area of the object or word that demands more visual attention.

The parafovea region covers around 10 degrees of the gaze point, expanding to 5 degrees on all sides of fixation. What is in the parafovea section is pre-processed to help the observer decide where to look next. It is mainly seen in reading studies; in other words, the observer is not looking at the information directly when the information is in the parafovea. The parafovea effect has been studied in reading studies. The last area, which is called the periphery, is beyond the parafovea area, and information in this region can be received completely and it is strictly extracted.

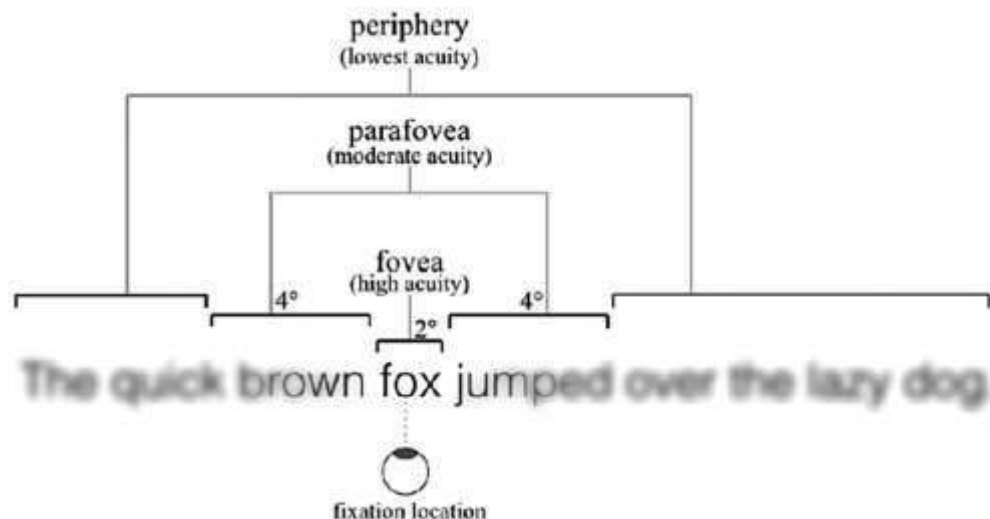


Figure 3 Visual acuity in fovea, parafovea, and periphery region. (Adapted from Rayner et al., 2016)

One other common feature which is measured in eye-tracking studies is degrees of visual angle ($^{\circ}$); since there is a close association between angular size and retinal image size, using angular units is important (Drasdo & Fowler, 1974; Legge & Bigelow, 2011). 1° of visual angle in central vision corresponds to 0.28 mm on the retina. As it is explained thoroughly in Godfroid (2020), to realize the notion of visual angle, one must assume that the observer is in the centre of a circle and one degree of visual angle equals $1/360$ of the circle.

Furthermore, it can be converted to minutes and seconds: $1^{\circ} = 60' = 3,600''$, which matches $1/60^{\text{th}}$ and $1/3600^{\text{th}}$ of a circle correspondingly (See Godfroid, 2020; for

review). According to Raney (1986) and Keating (2014), 1° of visual angle will frequently equal three to four letters in text-based eye-tracking studies for smaller font sizes.

To attain high-acuity visual information, people look around the environment. People usually move their eyes three to four times a second, which creates fixations and saccades. There are many types of eye-movement behaviors, and fixations and saccades are the most common ones, which are analyzed by linguists and psycholinguists. When the eye moves, there are intervals during which the eye is rather still, and the person is looking at a particular region in the visual field. Mostly, during fixations, the observer is obtaining and processing data from the spot where he or she is looking at the present. This region is named gaze point and can take 50 ms to over 500 ms (Rayner, 1998; Rayner & Morris, 1991). As it has been mentioned earlier, saccades are the second prominent attribute of eye-movement behavior. Saccades are fast eye movements that occur between two fixations. According to Holmqvist et al. (2011), saccades are the fastest movements that the human body is able to do, and they last about 30 to 80 milliseconds.

As it was mentioned earlier, saccades change the place of eye movement toward the point which needs more precision to be perceived by the human's vision, since the area of acute vision is restricted. Therefore, both humans and animals move their eyes to receive the new information of the object they are looking at, to cause new information to fall on the fovea in the eye, which is a high-acuity region. Different characteristics of saccades to be measured are amplitude, velocity, acceleration, and deceleration (e.g., Gilchrist, 2011). There are also very brief saccades 1 or 2 times per second, which normally cover less than 1° of visual angle (Engbert, 2006). Refreshing the visual input of the photoreceptor cells happens with the help of these unconscious brief movements. Both the place of fixation and the length of fixation are important and give information. The place demonstrates where the eye fixated and landed, which can hold information about ongoing cognitive processing. Length of fixation can answer many questions which Second language researchers are seeking for, such as attention, noticing, grammatical sensitivity, parsing preferences (Godfroid, 2020).

As it is stated in Kliegl et al., (2006), frequency, contextual constraint, and word length are three major predictors of eye-fixation duration. Having reviewed literature (e.g.,

Liversedge & Findlay, 2000; Rayner, 1998, 2009; Starr & Rayner, 2001), these factors: age of acquisition, word familiarity, part of speech, and concreteness can be added to the list of factors which impact fixation duration.

2.5.4. Eye tracking and second language learning

Eye-tracking methodology has gained attention recently as a valuable method to track the cognitive processing of learning. It is interesting that although eye-tracking has been used in many fields of psychology and psycholinguistics extensively, it has just commenced to be applied in second and foreign language learning research a decade ago. Eye-tracking methodology have been applied in diverse areas of language acquisition and bilingualism including grammar (e.g., Ellis et al., 2014; Godfroid et al., 2015; Hopp & León Arriaga, 2016; Keating, 2009, Boxell & Felser, 2017; Felser & Cunnings, 2012, Chamorro et al., 2016; Dussias & Sagarra, 2007), vocabulary learning (e.g., Elgort et al., 2018; Godfroid et al., 2013; Mohamed, 2018; Pellicer-Sánchez, 2016), instructed Second Language Acquisition (e.g., Alsadoon & Heift, 2015; Cintrón et al., 2015; Indrarathne & Kormos, 2017,2018) subtitle processing (e.g., Perez et al., 2013; Winke et al., 2013; Bisson et al., 2014), and language assessment (e.g., McCray & Brunfaut, 2018; Suvorov, 2015; Lee & Winke, 2018). To read and know more about them, one should refer to Godfroid (2020), who conducted a remarkable review on various eye tracking studies that were published by 2017 and categorized them. These are text oriented studies. Another paradigm that has been applied widely by applied linguists and psycholinguists to investigate their research questions, especially on spoken language, is the visual world paradigm.

Generally, in text-based studies using eye-tracking, overt attention (eye gaze) is linked to online processing of language. So, analysis includes durational measurement and normally longer fixations (on unfamiliar or less frequent words) are signs of longer processing time. On the other hand, visual world paradigm researchers use eye movement as a representational measure (Tanenhaus & Trueswell, 2006). Therefore, fixation in a visual word can uncover when linguistic representations become triggered in listeners' minds. Eye tracking with the text and visual world paradigm can be applied complementary manner in research to answer questions on language processing and

representation. In this paradigm, auditory linguistics and visual attention come together, to put it in other words, people see some images while they are listening to some pieces of language (e.g., Lee & Winke, 2018; McDonough et al., 2015; word recognition studies, e.g., Mercier et al., 2014, 2016).

Latif (2019) in his article reviewed studies from 2011 to 2018 which have focused on eye tracking analysis of L2 processing and the area of L2 that have been studied by eye tracking methodology, data collection, and analysis in each category were scrutinized, as well. He reviewed 71 papers and came up with eight different categories, including vocabulary processing, listening comprehension, reading comprehension, written text production, syntactic processing, oral communication, data validation, and text-based computer mediated communication. Among them, most papers (n=21) belonged to vocabulary processing, containing single words, idioms, collocations, and morphemes from readings. Also, there is one other review by Lai et al. (2013), who reviewed articles focused on eye tracking technology in learning, including articles from 2000 to 2012.

The questions that are investigated with the help of eye-tracking methodology in SLA concentrate on how learners direct their attention to unfamiliar linguistic objects. Therefore, as VanPatten and Rothman (2015) named it, acquisition, while it is being processed (e.g., Godfroid et al., 2010; Smith, 2010), and another category dedicated to processing outcomes of acquisition, which reflects how learners' attention is linked with learning outcomes. Eye tracking is increasingly being used in second language acquisition studies and language research. The reason, according to Rayner (1998, 2009), is that eye trackers have become more user-friendly (see Roberts and Siyanova, Chanturia, 2013, for a review of eye tracking methodology on SLA).

2.5.5. Eye tracking and Reading task

In reading studies, one of the important features using eye-tracking is no need to use any secondary task (Conklin & Pellicer-Sánchez, 2016). Especially with advanced eye trackers, which do not require participants wear an eye tracking device or use chin rest, assessing reading happens in an even more natural setting. Various types of eye movements are measured by eye-tracking. Including saccades, which are fast movements of the eye, fixations, when eyes stop on the spot, and regressions, which are

revisits of some parts of text which have been already processed; regressions are short, they are moving eyes back to the previous words in the text (for a comprehensive review see Conklin et al., 2018). As Just and Carpenter (1980) showed, eye tracking is based on the eye-mind link, which means eye movements are a measure of cognitive processing. One of the main terms which is used in eye tracking research is Area of Interest (AOI). AOI can be single words or phrases in a text on which eye movements need to be scrutinized by researchers. Measurements of AOI in reading are usually classified into two categories: early measures and late measures. First fixation duration, first pass reading time are early measures, and fixation count, second pass reading time, and total reading time are classified as late measures. It is claimed that early measures demonstrate automatic processing and primary phases of lexical access (e.g., recognition of orthography, phonology, and morphology) while late ones reflect controlled processing and lexical incorporation. One interesting point is that when a person reads a text, he or she does not fixate on every word but skips some words. When words are shorter and more predictable, the skipping rate is higher (Rayner, 1998; Rayner et al., 2005).

According to Rayner (1998), fixation durations are on average 225-250 milliseconds, and the mean for saccade size is 7-9 letters. All these eye movement measures are subject to being influenced by the length, frequency, and predictability of the stimuli (words); saccades take 20 to 30 ms, and their velocity can be as high as 500 degrees. New information cannot be perceived during saccades because they are so fast that “only a blur would be perceived” (Uttal & Smith, 1968, cited in Rayner, 1998; p. 373).

Enormous data from eye-tracking experience leads to a computational model, which is a computer algorithm. These models demonstrate researchers’ knowledge of how eye movements work. Concurrently, the models can be a facilitative factor for further experimental research. In reading research, there are two divisions of computational models: cognitive-control models, which refer to lexical processing (higher-level processing of information), and oculomotor models concerns role of low-level visual information such as the length of the words. These two models view the eye-mind link from different perspective and therefore they provide distinguished answer to this theory; features of cognitive control advocate a strong eye-mind link, whereas those

who vote for oculomotor control claim a weaker connection between eye gaze and cognitive processing (Godfroid, 2020).

Two well-known models in eye-tracking research in reading are SWIFT and E-Z Reader, briefly explaining them, having two computational models in mind, one could see that they are different. SWIFT stands for ([Autonomous] Saccade-Generation with Inhibition by Foveal Targets), according to which there are some fixed intervals between saccades as if each saccade takes the same time, unless eye gaze is fixed on an unfamiliar or difficult word, which causes saccades to occur longer than previous intervals. But in the E-Z model, it is different in the way that saccades do not happen after a fixed interval; they happen when the observer makes an educated guess, after seeing a lexical item, his or her mind unconsciously decides it is time to move the eye or not. To sum up, SWIFT is mostly autonomous, whereas E-Z Reader cognition plays a great role (Reichle et al., 2013; Reichle et al., 2006).

One paradigm that is used in registering eye movements in reading, when studying morphology in context, is named the boundary paradigm. The boundary paradigm is designed to help scholars to extract the information that a reader can extract from the parafovea (See Rayner 1975 for review). Bertram (2011) reviewed the studies that concentrated on morphological processing in reading. He claimed in his research that the first eye movement research on morphological processing dates to the late eighties (Inhoff, 1989; Lima, 1987).

In these two studies, the main question addressed the possibility of morphological processing parafoveally by use of the eye-contingent boundary paradigm (Rayner, 1975). For instance, in a noun phrase like ‘The exhausted cowboy’, whether ‘cow’ as a morphological component was extracted while eyes were still fixated on ‘exhausted’, and they did not find evidence for parafoveally encoded information. Another group of scholars dedicated their eye movement studies on morphological processing of compound words. As a result, they concluded that compound words are being processed according to dual-route model, which could be compositional or holistic (the former refers to unsegmenting compound words into morphemic parts, decoding the parts, and then putting them together, and the latter one engages access to the compound word as a whole).

In a reading study by use of eye-tracking methodology, Dolgunsöz and Sariçoban (2016), tried to investigate the distinction between eye movement behavior between participants with different levels of English reading proficiency, 57 participants went through two different experiment conditions of natural reading and isolated sentence reading while their eye movements were being recorded, the demonstrated that fixation duration and first pass time were affected by reading proficiency for all stimuli. They also showed that proficient readers had shorter revisits. Dolgunsöz, E. (2016), in another study by use of eye tracking, investigated the lexical inference from reading among 71 participants based on their vocabulary knowledge and reading proficiency to figure out their reading rate. He found the effect of users' knowledge on the inference of new words and reported that extra attention to an unfamiliar word did not show an effect in additional correct comprehension unless learners had a high level of vocabulary knowledge. He used "second pass reading time" as a marker of participants' use of contextual clues to comprehend new words meaning.

2.5.6. Eye-tracking and vocabulary research

Eye-tracking has been used broadly in vocabulary research, including single-word processing research (e.g., Elgort et al., 2018; Godfroid et al., 2013; Pellicer-Sánchez, 2016) and multiword studies (e.g., Carrol & Conklin, 2017; Siyanova-Chanturia et al., 2011; Titone et al., 2019; Yi et al., 2017). Godfroid, in her review study, which reviewed 17 studies focused on words, mentions that studies on single words mostly use less frequent words or pseudo words to ensure that participants do not know their meaning to investigate whether they can learn these words from reading. In contrast, in studies on multiword and idiomatic expressions, researchers commonly use frequent words, since they are investigating how multiword are retrieved from memory and how they are processed, especially in processing second language lexicon.

Pellicer-Sánchez (2020) illustrates in her work how eye-tracking has been a great help for scholars to discover the process of vocabulary learning from reading. Incidental vocabulary learning has been focused on in many eye-tracking studies, since there is a theory that vocabulary can be learned incidentally through doing other tasks, for instance, during reading, watching movies, or conversation (see Schmitt, 2010). Elgort

et al. (2018) named this kind of accidental vocabulary learning as contextual word learning. Thanks to eye tracking methodology, by means of which researchers can study overt attention and eye gazes online while participants are performing a task, and how they focus on unfamiliar words. As many studies have shown, less frequent and unfamiliar words draw more attention in comparison to more familiar words, which is represented by longer fixations in eye movement behavior (Godfroid, 2018; Mohamed, 2018; Pellicer-Sánchez, 2016; Warren et al., 2018).

For instance, in a study by Godfroid et al. (2013), 28 Dutch EFL learners' fixations on novel words were investigated; they were asked to read some short text including some control words, pseudo words, and target words, then they went through vocabulary recognition test. Their eye movement recordings disclosed that learners fixated on pseudo words longer than on control words. In a study by Pellicer-Sánchez (2016), participants who were L2 English learners were asked to read a story containing pseudowords. After eight exposures to the text, 86% of target nonwords were familiar to L2 readers. They also recall the meaning and form of 55 % of nonwords better. After three or four exposures to the text, L2 readers read the pseudowords faster.

Pellicer-Sánchez (2016) showed that accumulated times of reading while confronting the same pseudo word lead to a lesser fixation time, each time participants see the word again and is positively related to meaning recall. But it does not show a significant result between reading time and vocabulary score (Elgort et al., 2018). Godfroid et al. (2018) also carried out research in this area by asking 41 participants with various L1 backgrounds to read a longer passage, which involved 29 Farsi-Dari target words: each repeated 1 to 23 times in the reading. Participants went through three types of vocabulary assessments: form recognition, meaning recall, and meaning recognition. As results depicted, vocabulary learning outcome significantly relied on the number of exposures to target words.

In line with these studies on the effect of word frequency on eye movement behavior, an appealing study measured pupillary responses in visual word recognition. Having relied on previous research on word recognition, and the fact that word frequency significantly affects pupillary response. Haro et al. (2017) designed two lexical decision

tasks (LDT) (one normal and one delayed LDT) and recorded participants' pupillary response while they went through the tasks. They used the delayed response to study pupil dilations and revealed that pupillary response is affected by word frequency in both LDT and delayed LDT (LDT has been explained in 2.6).

A study on captioned movies by Montero Perez (2019) asked thirty L2 learners of French to watch a video with subtitles that included five pre-learned pseudo words to examine the impact of pre-learning on learners' attention to pseudo words; then applied first and total fixation duration and fixation counts, and revisit measurements. Results depicted that pre learning does not have an impact on learners' fixations, although some pre-learned pseudo words were skipped by learners in comparison to unknown pseudo words in captions. Generally, learners spent more time on unknown pseudo words.

In addition to the frequency of words which affect eye movement behaviour of readers, word length is another significant factor which has essential role in the placement of eye fixations and the duration of fixations. Paterson et al. (2015) studied participants' behavior in reading Arabic text and observed longer fixation time and refixation on longer words. They also mentioned that the length of words affects the eye landing position; readers usually fixate the center of short words and the beginning letter of longer words. Where eyes fixate influences the first fixation duration and the possibility of occurring regressions. This study on alphabetic language is in line with some other studies that have been carried out on base of Latinate languages, which demonstrated word length has an essential effect on where and how long the eye looks at the word (e.g., Joseph et al., 2009; Paterson et al., 2013; Rayner et al., 2011).

Kang et al. (2022) investigated the role of L1 and L2 glossary on reading behavior. They requested 81 Korean university students read a text with no gloss, L1 (Korean) gloss, and L2 (English gloss) while their eyes were recorded. Then they answered two vocabulary tests. Data analysis revealed that whether the text has gloss or not has an effect on lexical uptake. Results demonstrated that L1 and L2 glosses do not show significantly different effects on readers' behavior, whereas the presence of both glosses enhances the establishment of form meaning associations.

The subject of how the mind can process multi words has always been an appealing topic for linguists and psycholinguists to study, eye-tracking is a useful device to scrutinize this area more profoundly, for example, whether L2 learners show faster reading time when they know multi-words or idioms (e.g., idiom processing, Cieřlicka and Heredia 2017; Kessler et al., 2020; Siyanova et al. 2011; Titone et al., 2019; Yi et al., 2017; Wray, 2008; and collocation study (e.g., Sonbul, 2015). Carrol and Conklin (2015) discussed in their study how eye-tracking might be beneficial for processing formulaic language. In his study, he started by reviewing research which focused on the single word processing by eye tracking (factors that influence fixation time, such as frequency of the words), and then he mentioned that for multi-words, not only the frequency of the whole unit is going to be considered, but the frequency of each component has an influence on reading the word. To study multi-words, other factors must be taken into consideration, such as the n+1 and n+2 effect (it refers to words next to the word the eye fixated which normally it is on parafovea area), which can influence processing of multi words which is called the preview effect (see Cutter et al., 2014; Juhasz et al., 2009 for review).

There is a large database of eye movement studies on English compound word processing collected by Schmidtke et al. (2020). A total of 440 subjects took part in this eye-tracking experiment and they read unspaced compound words, such as goalpost in a sentence context. Three studies have been carried out, as the result demonstrated that the features such as the length of compound words, left/right component frequency, compound word frequency, and semantic transparency were the most consistent main effects on eye movements and durational measures.

Phrasal verbs as a category of compound words or multi words and how phrasal verbs are processed is a debate among linguists and psycholinguists. Wisintainer and Mota (2017) inspected online processing of phrasal verbs by advanced learners of English. They asked eight advanced learners to read sentences that contained phrasal verbs and corresponding one-word equivalents for phrasal verbs while their eye movements were registered. Eight Brazilian native speakers of Portuguese and eight native speakers of English took part in this experiment; researchers were to find out whether there is dissimilarity between the processing of literal phrasal verbs and lexical verbs. Participants read 96 sentences, 16 of which contained literal phrasal verbs, 16 contained

lexical verbs (e.g., “beautiful models usually PUT ON a lot of makeup during fashion shows. vs. beautiful models usually APPLY a lot of makeup during fashion shows” (Wisintainer & Mota, 2017, p. 725). Also, participants read 64 sentences containing fillers. Sentences appeared on the PC screen and their eye movements were recorded by SMI 500HZ; the measures of first pass reading time depicted that native speakers allocated more attention to phrasal verbs than lexical verbs, which can be an indicator of more time which is needed to process sentences containing phrasal verbs.

2.5.7. Eye tracking and priming

As one can infer from related literature of semantic priming in different studies, both in psychology, psycholinguistics and linguistics, the most essential measuring factor in priming studies is reaction time. There are many different studies in the history of priming (as it has been mentioned in the previous part) that have recorded reaction times. Recently, online measurement such as eye-tracking is being used in studies, and some studies mix two methods of recording reaction times, traditional and recording eye movements in semantic priming tasks (e.g., Schmauder et al., 2000; Odekar et al., 2009).

Calvo and Castillo (2009) in their study investigated the role of covert and overt attention in word recognition. They desired to examine whether word recognition can occur by covert attention in the absence of overt attention. Therefore, they designed the condition that permits only covert attention by inhibiting eye fixations on the prime. Primes appeared for 150 ms in 2.2° from fixations in the parafovea region. Also, primes were masked when participants made saccades toward them. Consequently, primes could not be fixated. They supposed that placing the primes in the parafovea region caused them to remain unattended at first, although they might get attention later. In the other condition which covert and overt attention were assumed to take place together, primes were presented in the fovea part (where eyes would fixate) without masks.

Calvo and Castillo (2009) addressed the second inquiry of their research, which was whether the involvement of covert attention affected only word form or word meaning. They also designed lexical decision tasks (LDT) according to two paradigms of

semantic priming and repetition priming. They asked 48 undergraduates to answer lexical decision tasks (whether the string of letters they saw was a word or a non-word) while targets were preceded by identical words (repetition priming) or semantic priming (related in meaning). The task encompassed 78 target words, 78 related primes, and another 78 words that were unrelated. Their eye movements were recorded by Eye Link while they went through the LDT. The result demonstrated that if unattended words could be covertly attended, repetition and semantic priming occurred. Semantically associated and related conditions facilitate LDT rather than unrelated prime-target conditions. They also depicted that not only word forms, but word meanings can be processed by covert attention without overt attention. Priming was reported to be stronger when words got overt attention, too. In a nutshell, they claimed that both the form and meaning of words can be detected in the lack of fixation on the words.

Odekar et al. (2009) carried out research on the validity of the eye-tracking method to investigate semantic priming. To find out how eye-tracking methodology can be a useful tool to study the priming effect, they asked 100 native English adults (age range 18 to 26) to do the task in which there were 260 prime word-picture target pairs. In their design, each prime was presented in one condition highly associated with the target and in two low associated conditions with nontarget images. By having measured fixation durations, they revealed that there were greater fixation durations for semantically related primes, and shorter latencies were recorded compared to nontargets. Since before this phase, they performed a traditional priming task and recorded reaction times; results were correlated with eye movement measurements, which could be a proof of validity for eye tracking methodology to be applied in semantic priming studies.

Having reviewed the literature, one can see that in single-word reading, orthographic and phonological form similarity facilitates word processing (e.g., Andrews & Lo, 2012; Davis & Lupker, 2006). As mentioned earlier (in the priming part), masked priming is the most well-known technique to inspect word processing. In masked priming, a prime word is shown to the participant for a short time, too quick for the subject to be aware of that, and lingering enough for the brain to process that (about 40 to 60 ms). Primes usually are usually demonstrated with small letters followed by a mask, for example, ##### symbols, whereas targets are commonly shown by uppercase letters. When the prime is orthographically neighbor of the target (e.g., corn-horn), it

usually slows down the processing of the target word (see Forster and Davis 1984, as a pioneer of masked priming). Furthermore, eye tracking has been used in subliminal priming studies, and it has been shown in studies that motivation can influence where they look or fixate. Caspi et al. (2006) confirmed that prime may cause a shift of someone's gaze toward or away from a particular stimulus, and they also linked this to "terror management" defence.

According to some scholars, the mask priming effect on visual words depends on affected by type of tasks. Kinoshita and Norris (2012) mentioned that it is implicitly assumed that early processes in word detection in the masked priming paradigm are automatic, although they have revealed that this is not the case for various kinds of tasks. For instance, having reviewed the related articles, they stated that the effects of semantic priming are weaker in lexical decision tasks but strong in semantic categorization tasks. They also claimed that by meticulously selecting, the task priming effect can happen for non-words and pseudo words, or even some priming effects of words might disappear.

In a study by Marelli (2013), a masked priming study was conducted using eye tracking methodology to explore whether visual word recognition for complex words always relied on decomposition of the word into its morphemic constituents; to put in other words, whether it is only orthographic factors that have an impact on breaking down the words or whether semantic factors have role as well. Twenty-seven Italian student took part in the study to answer 150 prime-target pairs while their eye movements were recorded by EyeLink 1000 HZ. Prime-target pairs were divided into three categories of relate, semantically unrelated, and orthographically related. There were also 150 control prime-target pairs.

Experiments start with a fixation point trial in the upper-left corner of the PC screen. It is followed by a hash mark mask, which is presented for 500 seconds stayed on the screen. After the mask, prime appeared for 35 seconds, also a "0" in the right-hand position, then substituted by the target stimulus, which remained on the screen for 700 milliseconds, along with a number of 1-8, which was presented on the right side. Subjects were required to read the words and numbers; they were told that they would be asked questions about the words or numbers. They were trained to answer with

yes/no on the response pad. They revealed that to gain lexical identification, morpho orthographic separation is not always required.

Carrol and Conklin (2017) reported cross language idiom priming effect in their study; Chinese/English bilinguals took part in this study. There are many studies that have demonstrated native speakers benefit from the faster processing of highly frequent idioms rather than less frequent ones. Participants went through two experiments in which reading Chinese idioms/controls and English idiom/control by bilingual Chinese native speakers and monolingual English native speakers were compared. In the first experiment, they tried to find out whether Chinese native speakers read the final word of a translated idiom (Chinese to English) faster in comparison to control words (e.g., idiom: draw a snake and add feet vs. control: draw a snake and add hair). The results revealed shorter reading time for the final word when it is in the idiom condition. Carrol and Conklin (2017) used this as evidence that L1 knowledge can be at the service of activation of known lexical combinations of L2. In the second experiment, they investigated idioms with both their figurative meaning and their literal meaning. They expected that reading the idioms that have figurative meaning would be more difficult for native speakers of Chinese.

Haugland (2018), in his master's thesis, did research on the word neighbor priming in sentence reading. He asked 31 Norwegian undergraduate students who were learners of English to read the single sentences on Pc screen while their eyes were recorded by SR Research Eyelink 1000 Plus Camera. They examined the impact of the distance between prime and target words and came out with the result that when the distance between prime and target was 3 words, it could cause longer gaze durations. They concluded that the more proficient L2 readers are, the more influenced they are by word overlapping. To sum up, just like L1 readers, expert L2 readers keep word forms longer than less skilled L2 learners.

Chapter 3. Methodology

Performing the study required meticulous planning and execution. This chapter delves into the intricacies of stimulus design. Each section pertaining to subjects, stimuli, phrasal verb familiarity, Likert scale, SMI eye-tracker, recognition post-test, and the overall process will be thoroughly explored. Numerous studies have dedicated considerable effort to investigating the processing and learning of phrasal verbs. Across these studies, a common thread emerges: the selection of the most frequently used phrasal verbs, as adapted by various scholars (e.g., Gardner and Davies, 2007; Hunston, 2002; Liu, 2011; Schmitt, 2008). As previously highlighted (refer to chapter 2 for a comprehensive review), the rationale behind compiling a list of frequently used phrasal verbs serves to benefit both EFL/ESL teachers and learners. This curated list equips them with the necessary knowledge of highly utilized phrasal verbs, facilitating acquisition and instructional strategies (Schmitt, 2004). To conduct this study, all data were meticulously collected by the principal researcher, who also designed and selected the phrasal verbs under examination, a process that will be elucidated in this chapter.

3.1. Participants

30 upper-intermediate to advanced English learners, among whom some speak English every day in their workplace and some do not. They were right-handed. They had normal to near-normal vision. They were all right-handed. There were 10 males and 20 females. The age ranges from 21 to 40, the average is ~ 30 (There was just one person, 46). Regarding university degrees, 16 participants gained their bachelor's and 12 had their master's degree, 2 PhDs (Appendix D, figure of distribution of the research sample). Fifty-five invitation calls had been sent to all colleagues and advanced English learners in different institutes, 41 receivers admitted participating in the experiment, from which 30 took part in the study. Participants were given a gift card at the end of the experiment.

3.2. Instruments

3.2.1. Consent form

The consent form, crafted in Persian and adapted from Garnier's (2016) template, comprised 10 concise statements. Each statement was designed to be easily understandable and was to be thoroughly reviewed and signed by both the researcher and the participants. (See Appendix A). The consent form emphasizes that participation is entirely voluntary and assures participants that their privacy and anonymity will be respected throughout the study. It explicitly states that the results of the research are unknown and will remain confidential, accessible only to authorized personnel. Moreover, participants are informed that they have the right to request the deletion of their data at any point without facing any consequences. This commitment underscores the non-invasive nature of the study and reinforces the principle of participant autonomy and control over their information.

3.2.2. Language background test

To account for individual variability in participants' language proficiency and exposure, a language background questionnaire was administered before the main experiment. This instrument collected self-reported data on several key factors, including the age of onset of English language learning, the context of acquisition (formal instruction, immersion, self-study), and the frequency of current English usage in both academic and professional settings. Participants were asked to estimate the average number of hours per day and per week during which they actively engaged with the English language through reading, writing, speaking, or listening activities.

This background information served several purposes. Primarily, it provided contextual depth for interpreting the main eye-tracking and behavioural data, particularly in relation to individual differences in second language (L2) experience. By correlating participants' performance with their reported language histories, the study aimed to explore whether increased exposure to English—especially in meaningful,

communicative settings— correlates with more efficient lexical processing or more native-like attention allocation during reading tasks.

Additionally, the questionnaire allowed for screening out participants with unusually high or low exposure to English, ensuring greater sample homogeneity and internal validity. This step was especially important because the experimental stimuli—phrasal verbs—are known to pose challenges even to advanced L2 learners, and differences in input frequency may significantly shape recognition and processing patterns (e.g., Ellis, 2002; Godfroid et al., 2015).

All responses were treated with strict confidentiality and used anonymously to investigate the relationship between participants' language backgrounds and their performance in the lexical decision task. While the primary analyses in this thesis do not directly quantify correlations between language exposure and processing measures, the background data provides a valuable reference point for interpreting inter-individual variation in the experimental results and lays the groundwork for future research on the impact of L2 input frequency on multiword unit processing.

3.2.3. Likert Scale Familiarity test of phrasal verbs

To ensure the selection of appropriate and challenging stimuli, a Likert-scale familiarity rating task was designed and implemented in the preparatory phase of the study. The primary aim was to identify less commonly encountered phrasal verbs among advanced L2 learners of English, particularly within the target population of Persian-speaking learners. This step was crucial to control for item familiarity and avoid ceiling effects in processing accuracy. The test was constructed using a comprehensive inventory of phrasal verbs extracted from the Destination C1 & C2 vocabulary series, a resource widely recognized for its relevance in advanced English language instruction. From this list, the researcher selected a diverse subset of phrasal verbs that covered a range of syntactic and semantic properties. Participants were then asked to rate each phrasal verb on a 5-point Likert scale (ranging from “Not familiar at all” to “Very familiar”) based on their perceived familiarity and frequency of use in everyday language.

The familiarity test was distributed approximately one month before the main experiment, allowing the researcher to compile a corpus of candidate phrasal verbs that were consistently rated as less familiar across the participant sample. Importantly, the administration of this pre-test involved a diverse pool of advanced Persian-speaking learners, thereby increasing the ecological validity of the results and ensuring that the selected stimuli reflected realistic processing challenges for the target population.

To enhance the reliability and validity of the familiarity ratings, the form was reviewed and piloted with academic colleagues, including instructors with expertise in advanced English instruction and second language assessment. Minor adjustments were made based on their feedback, particularly in phrasing instructions and confirming the cultural appropriateness of certain expressions. This collaborative process ensured that the familiarity test was linguistically precise, culturally sensitive, and methodologically sound.

Although the familiarity data were not included in the final statistical analyses, they played a critical role in stimulus design, helping to refine the experimental material and improve the overall sensitivity of the eye-tracking task to subtle differences in lexical processing. The final selection of phrasal verbs represented a carefully balanced mix of structurally and semantically varied expressions, all of which were confirmed to be relatively unfamiliar to participants, thus enhancing the interpretability of observed processing effects. A sample of the familiarity questionnaire and summary of its results can be found in Appendix B.

3.2.4. Semantic Priming Task (lexical decision task)

The Lexical Decision Task (LDT), as outlined in the theoretical background, involves presenting participants with a sequence of letter strings and asking them to decide as quickly and accurately as possible whether each string forms a real word or a non-word. This paradigm is widely used in psycholinguistics and cognitive psychology to investigate word recognition, lexical access, and semantic processing.

The LDT was first introduced by Meyer and Schvaneveldt in the 1970s, whose pioneering work sought to uncover the structure of long-term memory and the cognitive processes underlying word retrieval. Their seminal findings demonstrated that participants responded more quickly to semantically related word pairs (e.g., bread–butter) than to unrelated ones (e.g., nurse–butter), a phenomenon now known as semantic priming. This effect supports the idea that words are stored in interconnected networks in the mental lexicon and that activation spreads between related concepts, thereby facilitating recognition.

Over the decades, the LDT has become one of the most commonly used tasks in experimental psycholinguistics due to its efficiency, sensitivity, and versatility. It serves as an indirect measure of lexical access, relying on reaction times to infer underlying cognitive processes. Importantly, the task allows researchers to probe aspects of processing that participants may not be consciously aware of, making it particularly valuable in studies where overt self-report measures may be limited by social desirability bias or lack of introspective access. This implicit nature makes the LDT especially suitable for investigating automatic processes such as priming, familiarity, and processing fluency.

In more recent years, technological advancements have allowed researchers to implement LDTs through experimental software platforms such as PsyToolkit, EPrime, and PsychoPy. These tools offer precise control over stimulus presentation and response time measurement. However, in the present study, the LDT was manually developed and implemented by the researcher, due to the limited compatibility between the SMI eye-tracking device (used for the concurrent eye movement recording) and the aforementioned experimental software environments.

Despite these technical constraints, care was taken to ensure the timing precision and consistency of stimulus presentation, with all trials being embedded directly into the SMI Experiment Center environment. This ensured smooth integration between the behavioural and eye-tracking data, maintaining the scientific rigor of the LDT while tailoring its design to the technical needs of the study. Thus, the Lexical Decision Task in this study not only measured participants' speed and accuracy in recognizing phrasal

verbs across different prime–target conditions but also functioned as a central paradigm for exploring attentional allocation, semantic processing, and implicit learning under time pressure.

3.2.5 SMI REDn Scientific series Eye Tracker 60 HZ

The eye-tracking equipment used in this study was the SMI REDn Scientific Series Eye Tracker, developed by SensoMotoric Instruments (SMI). This system is a remote, screen-based eye tracker that is physically mounted beneath the monitor. Compact in design, the device measures approximately 35 cm × 2 cm × 2 cm and weighs only 75 grams, making it unobtrusive and ideal for experiments requiring minimal participant distraction or interference.

The SMI REDn operates at a sampling rate of 60 Hz, which means it captures 60 gaze data points per second. While this rate is considered moderate compared to high frequency research-grade trackers (e.g., 120 Hz or 250 Hz), it is sufficiently accurate for reading studies, visual attention tracking, and cognitive processing experiments such as the one conducted in this thesis. The device reports an average accuracy of 0.4 degrees of visual angle, which ensures reliable fixation detection for tasks involving short word stimuli like phrasal verbs.

The tracking range of the device is approximately 50 cm × 35 cm at a viewing distance of 65 cm, offering a generous area for natural head movements without requiring participants to use a chin rest. For this study, the device was paired with a 20-inch desktop monitor, which falls well within the supported screen size range of 10 to 27 inches, allowing for a flexible experimental design while maintaining the spatial accuracy of gaze detection. The eye tracker was connected to the desktop computer via a USB 3.0 interface, ensuring fast data transfer and minimal latency in real-time tracking. The successful operation of the device relies on the use of three key software components:

1. iView RED – This software manages the communication between the eye tracker and the host computer, ensuring calibration and data synchronization.
2. Experiment Center – This application is used to design and structure experimental tasks. In this study, all stimuli and task parameters for the lexical

decision task (LDT) were programmed using this tool to allow seamless integration with gaze data.

3. BeGaze – This is the data visualization and analysis platform, enabling researchers to replay eye-tracking recordings, define Areas of Interest (AOIs), and extract fixation-based metrics such as fixation duration, count, and glance duration.

Together, these tools provided a fully integrated environment for stimulus presentation, gaze recording, and data interpretation. Despite being limited to 60 Hz sampling, the SMI REDn system proved effective for the present study's goals, which centered on fixation-based metrics rather than high-speed saccadic movement. The unobtrusive nature of the setup also contributed to more natural reading behavior, ensuring the ecological validity of the eye movement data collected during the lexical decision task. Figure 4 provides a visual representation of the SMI REDn device used in the experimental setup.



Figure 4 Eye tracker RED, a scientific series device connected to the bottom of the computer screen.

3.2.6. Vocabulary recognition task

To assess any incidental learning effects resulting from repeated exposure to the target items during the experiment, a post-experiment vocabulary recognition task was administered immediately after the lexical decision task (LDT). Although the data from

this task were not formally analysed within the scope of this thesis, its inclusion was methodologically important for identifying possible gains in word familiarity that may have occurred as a result of participation in the experiment.

Participants were presented with a list of all 60 target phrasal verbs used in the experimental trials, displayed one at a time on the screen. For each item, they were asked to indicate:

1. Whether they had seen or remembered the item during the experiment (Yes/No),
2. If Yes, how many times they believed they had encountered it (a subjective frequency judgment).

This task served two main purposes. First, it was intended to identify whether the participants had incidentally learned or become familiar with certain phrasal verbs merely through exposure, which could have implications for interpreting any priming or processing advantages observed in the main task. Second, it offered a way to evaluate participant engagement and attention by allowing the researcher to cross-reference participants' memory judgments with the actual distribution of item exposure across conditions.

The inclusion of this task is consistent with previous psycholinguistic and second language acquisition studies that examine implicit vocabulary acquisition and word form recognition (e.g., Godfroid et al., 2018; Pellicer-Sánchez, 2016). Although this post-task was not designed to yield a separate set of quantitative results, it provided an important qualitative control mechanism to assess the potential confounding effect of item repetition or increased familiarity over time.

From a theoretical perspective, the task also aligns with dual-processing frameworks in L2 vocabulary research, which suggest that repeated exposure to unknown words—even without explicit instruction—can lead to increased lexical familiarity (Barcroft, 2009; Webb, 2007). Including such a task helps address concerns regarding the temporal sensitivity of priming effects, especially in experimental designs where target items appear more than once across different conditions or participants.

In practical terms, the recognition data were not used in the primary analysis because the goal of this study was to focus on real-time processing measures, such as reaction time and eye movements, rather than post-hoc vocabulary learning. Nonetheless, the post-experiment vocabulary recognition task adds to the overall methodological rigour of the study by demonstrating that attention was paid to possible learning effects across the duration of the task.

The recognition task was presented using the same software platform (Experiment Center) and on the same computer as the main lexical decision task. The entire task took approximately 5–7 minutes per participant. No corrective feedback or scoring was given, as the aim was to gather observational data rather than to assess vocabulary knowledge per se. A sample screenshot of the task format is included in Appendix C.

3.3. Items Selection Process

In this study, 60 less frequent phrasal verbs among pre-advanced English learners were chosen to create the experimental task. To ensure that these phrasal verbs were genuinely less familiar to the target population, a Likert-scale familiarity test was conducted with 110 phrasal verbs. These items were initially extracted from C1 and C2 levels of the Cambridge English preparation lists, known for covering a broad range of advanced vocabulary.

The familiarity test was distributed among a group of advanced English learners and speakers, and based on their responses, the 60 phrasal verbs rated as least familiar were selected for the main task. This selection process was critical in maintaining the validity of the semantic priming investigation. By using less familiar phrasal verbs, the likelihood that participants already knew or recognised the target items was reduced, allowing the experiment to more effectively measure genuine semantic and attentional processing rather than retrieval from prior knowledge.

The goal of this design was to assess how semantic priming operates when participants process novel or low-frequency lexical combinations. To do so, the study focused not only on the full phrasal verbs, but also on their structural components—namely, the

main verb and its corresponding particle. The particles selected (out, off, on, in) are among the most frequently used in English phrasal constructions. Their familiarity ensures that any observed difficulty or delay in recognition could more reliably be attributed to the novelty of the verb–particle combination rather than to the particle itself.

To develop unrelated prime–target pairs, an additional 60 phrasal verbs were selected that matched the target phrasal verbs in letter length and structural format but bore no semantic or associative relationship to them. This ensured that any differences in processing time or fixation behavior could not be attributed to differences in surface level features. In addition to the related and unrelated primes, 60 pseudowords were generated using the Wuggy application—a specialized software tool commonly used in psycholinguistic studies to create nonwords that resemble real words in orthographic and phonological structure. These pseudowords were constructed to closely resemble English verbs, with many sharing two or more letters with the actual target words. Some were created by slightly altering the letter sequence of real words (e.g., gifure derived from figure), while others were designed to retain the general morphological appearance of verbs while remaining clearly non-lexical.

The inclusion of pseudowords served a dual purpose. First, they acted as a baseline condition for measuring non-lexical processing effort, and second, they enabled researchers to observe how participants responded to unfamiliar strings that mimicked real words in form but lacked meaning. This careful design of stimulus items across different prime–target relationships strengthened the internal validity of the experiment by isolating the effects of semantic relatedness and lexical familiarity.

3.4. Designing the task

The lexical decision task in the priming study concludes of prime and the target. In this study, there are six conditions, each of which contains 60 words; hence, there are 300 pairs in total. First condition is related prime-target words such as amp up and amp; second condition embrace unrelated prime and targets for instance bag out and amp; the other condition are “neuter” condition amp and amp; forth condition allocated to pseudo

words (pseudo prime- pseudo target) which were created meticulously to be similar to the targets like jaf up, jaf; the last condition encompasses sixty fillers which were combination of single word (e.g., dig/dig) or multi-word (e.g., dive in/dive in). To present these 300 words to the participants, they were pseudo randomly designed in two different counterbalanced sections; all participants saw the 300 words on the computer screen, but in a different order. Each trial started with cross fixation in the center of the screen page to locate the subject's eyes at the center. Fixation frame lasted for 1000 ms (about 1 second) followed by the prime for 50 ms (e.g., chew out) preceded by a blank frame for 50 ms, then the target word (e.g., chew) appeared and remained on the screen for 500 ms, followed by a response page for 2000 ms (about 2 seconds) during which, participants were asked to decide whether the springs of word they have just seen was a word or non-word by pressing the left mouse click for words and right mouse click for non-words.

As can be seen in Figure 5, the Second Experiment held the same situation with the same words except for related prime-target pairs (e.g., “ward” as a prime and “ward off” as target) to investigate the probable priming effect of the first word part on the phrasal word. In this block, participants went through 300 trials, as well. In this experiment, after the fixation cross, the prime words were verbs (e.g., chew) and the targets were phrasal verbs (e.g., chew out). Primes for 50 ms following by a blank page for 50 ms and then targets, which in this experiment were phrasal verbs that were represented for 500 ms preceded by the response frame on screen on which has written “word” on the left side and “non-word” on the right side accordingly same as left mouse click for word and right mouse click for non-word. On the response screen, no mouse cursor was designed in order not to distract and slow down the participants from responding.

In total, the task includes two blocks and two counterbalanced of each block. Each contained 300 trials; each participant went through a lexical decision task for 600 trials in total. Namely, Block 1 has A version and B version, which is the counterbalanced version of the A version (to have variable stimulus order in the task), so that no stimulus is always the first one or as a fixed last one. Block 2 also has A and B versions. Participants went through one version of Block 1 and one version of Block 2. Deciding on which Block version would be allocated to which participant, excel randomization

formula was used. Henceforward, choosing the task was carried out randomly for all thirty participants. Here is the example of one trial of block one, which depicts related prime/target pairs, unrelated prime/target pairs, identical prime/target pairs, and pseudo prime/target pairs.

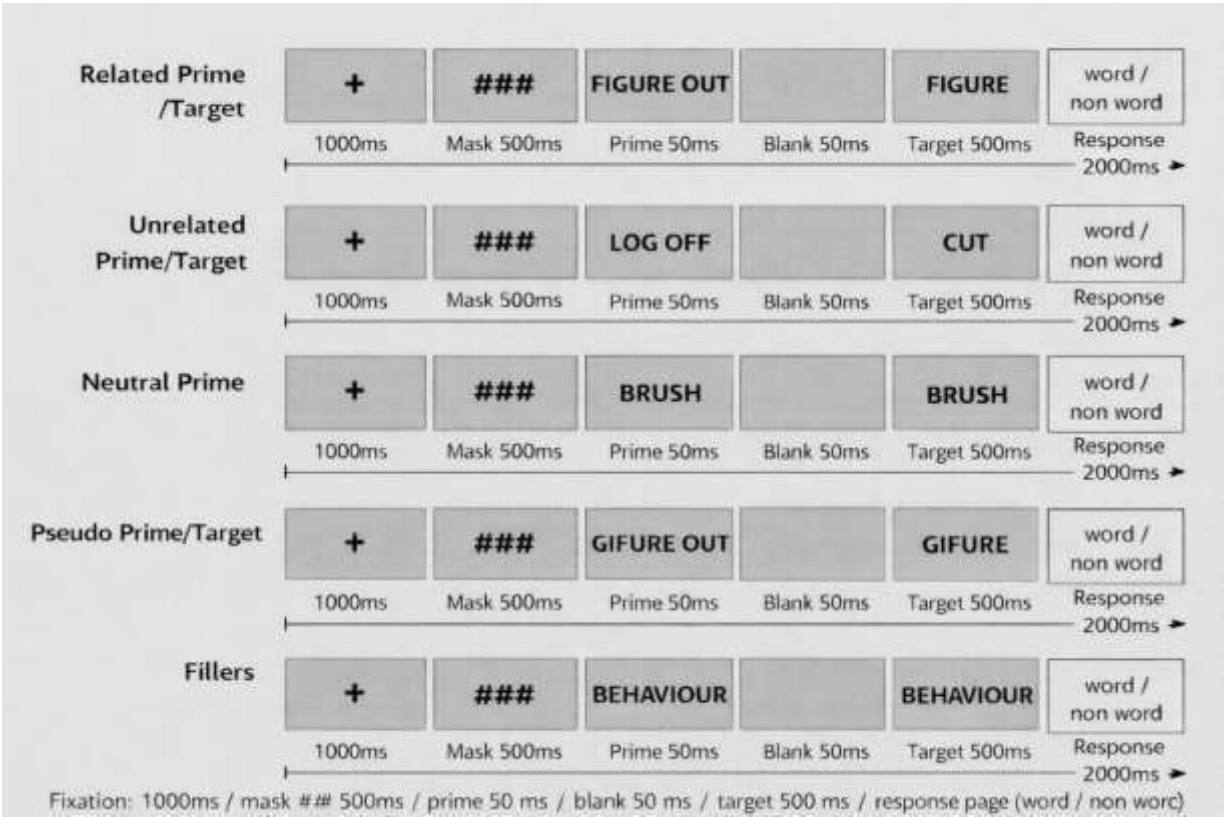


Figure 5 Examples of five different trials. Related prime/target (figure out/figure), unrelated prime/ target, identical prime/target, pseudo prime/target pair, fillers.

3.4.1. Area of interest

Area of interest (AOI) is that part which is supposed to be investigated and analyzed in an eye tracking study. In this study, all words were considered as an area of interest as a whole, since fixation behaviour on each lexical item was relevant for the analysis. In addition, phrasal verbs were divided into two areas of interest, including the main verb and its particles, in order to capture more detailed information about how attention was allocated to each component of the phrasal verb during processing.

Since the version of SMI that was used in this study did not identify AOI automatically, all areas of interest were defined manually in the software. This required drawing AOIs for each word and for each component of the phrasal verbs separately. Although this process was time-consuming, it allowed for more precise control over the data and ensured that fixation measures were accurately assigned to the intended linguistic elements. This manual definition of AOIs was particularly important for phrasal verb analysis, where understanding the interaction between the verb and the particle is central to identifying processing patterns. By separating the two elements into distinct AOIs, the study was able to determine whether participants fixated longer on the verb or the particle, offering insight into whether meaning construction was driven more by the base verb or modified through the particle. This distinction is especially relevant in second language processing, where learners may vary in their sensitivity to multi-word constructions.

Furthermore, defining individual AOIs ensured that overlapping fixations were minimized and that data loss due to ambiguous gaze allocation was reduced. In line with previous research using similar manual AOI setups (e.g., Godfroid et al., 2015), this approach supports greater validity of the eye-tracking measures. The resulting data enabled fine-grained comparison of fixation durations and counts across different word classes and syntactic roles, contributing to a more nuanced understanding of lexical processing in context.

3.4.2. Pilot study

Before running the main experiment, a pilot study was conducted to ensure the feasibility and clarity of the lexical decision task and to fine-tune the technical setup using the SMI REDn Scientific Series eye-tracking system. The purpose of this preliminary session was to evaluate the functionality of the experimental software, the calibration accuracy of the eye tracker, the timing of stimulus presentation, and the general comprehensibility of the task instructions.

The pilot study involved one advanced English learner, whose profile matched the intended participant demographic. The trial run followed the same procedure planned

for the main experiment, including calibration of the eye-tracker, warm-up trials, and the full version of the task with randomly assigned prime–target pairs.

Although the data from the pilot session were not formally analysed or included in the final dataset, the pilot helped to identify several minor issues related to stimulus alignment on the screen and the pacing of the trials. For example, slight delays in the transition between stimulus and response screens were observed and corrected. In addition, feedback from the participant confirmed that while the instructions were generally clear, they could be slightly reworded to reduce ambiguity, especially concerning the nature of the nonword responses. Adjustments were also made to the visual layout of stimuli to optimise fixation capture within the defined areas of interest (AOIs). Based on these observations, refinements were implemented in both the experiment design and software settings to improve data accuracy and participant experience. Conducting this pilot was a crucial step in validating the technical and procedural integrity of the study before recruiting actual participants.

To evaluate the functionality of the task design and the technical settings before the main experiment, a pilot study was conducted with three participants who were not part of the main study population. The primary aim was to assess the clarity of task instructions, the responsiveness of the eye-tracking system, and the timing and presentation of stimuli. The pilot also helped identify any technical or procedural issues that could interfere with data collection. Feedback from the pilot participants informed minor adjustments to the experimental instructions and interface layout to enhance usability and reduce ambiguity. Prior to the task, a 9-point calibration procedure was carried out for each participant using the eye-tracking system to ensure accuracy in gaze recording. Participants were seated approximately 60–65 cm from the monitor in a well-lit, quiet room. Although a chinrest was not employed, posture and distance were kept consistent to stabilize head position. Calibration accuracy was reviewed before proceeding, and recalibration was done if any drift or inaccuracy was detected. This preparatory phase helped validate the technical setup and refine the procedure, ensuring smooth execution in the main data collection phase.

3.4.3. Procedure

As previously explained, the initial list of phrasal verbs was extracted from the C1 and C2 levels of the Cambridge English Vocabulary Profile and Destination series. To identify less frequent but pedagogically relevant items, a group of advanced English learners—selected at random—were asked to complete a Likert-scale familiarity test (see Appendix B). From an initial pool of 110 phrasal verbs, the 60 least familiar items were selected for inclusion in the main experiment based on participant ratings. This ensured that the stimuli would be sufficiently challenging and unlikely to be easily recognised due to high exposure.

The lexical decision task (LDT) was designed to be compatible with the SMI REDn Scientific Series eye-tracking system. The experiment was created using the iView Experiment Center (version 3.7) and displayed on a monitor with a resolution of 1600×900 pixels. Due to limitations with stimulus presentation software, all target words and nonwords were prepared as high-resolution image files (JPEG format) and manually uploaded into the Experiment Center interface. The experiment took place in a quiet, dimly lit room to minimise external distractions and ensure stable eye-tracking calibration.

Participants were recruited through invitation letters and personal contacts. Many of the participants were English teachers, professional translators, or individuals who regularly use English in academic or professional contexts. Due to COVID-19 restrictions, participant availability was limited, and the entire data collection process extended over a six-month period.

Each participant was tested individually. Upon arrival, they were first provided with a consent form, which they were asked to read and sign. The form explained the purpose of the study, emphasised voluntary participation, and assured participants of full confidentiality. It also clarified that the experiment involved no financial cost or physical risk, and that participants could withdraw at any point without penalty.

Following consent, participants completed a background questionnaire that collected data on their English learning history, including the age they began studying English,

the contexts in which they use the language, and how frequently they use English in daily and professional settings. This background data provided important context for interpreting individual differences in performance and attentional behaviour.

After completing the background questionnaire, participants were seated in front of a 20inch monitor connected to the SMI REDn eye-tracking system. The experimenter then explained the nature of the task, and a practice session of 15 warm-up trials was presented. These warm-up items were designed to familiarise participants with the task format and response procedure, but contained no target words from the main experiment, thus avoiding any learning or priming effects. During each trial, participants viewed a fixation cross followed by a prime-target pair, and then responded on a decision screen by clicking either "word" or "non-word" as quickly and accurately as possible. Reaction times and eye movement data were recorded throughout. After completing the warm-up session, participants were encouraged to ask questions and proceed to the main task only when they felt fully comfortable with the procedure.

The full lexical decision task included three counterbalanced blocks in which each target word appeared in three distinct prime conditions: related, unrelated, and neutral. For example, the target word *amp* might be paired with *amp up* (related), *bag out* (unrelated), and *amp to* (neutral). This design allowed for comparisons of how prime–target relationships influenced both eye movements and lexical decision performance. The full task lasted approximately 40 minutes, during which participants were allowed to take a short break after every 10 minutes to avoid fatigue. Task order was randomised using an Excel macro, ensuring that each participant encountered a unique but controlled sequence of trials (see Appendix E for trial distribution details).

At the end of the session, participants completed a vocabulary post-recognition test. This test presented all 60 target words again and asked participants to indicate whether they recognised the word and how many times they had seen it during the experiment. Although the data from this post-test were not included in the main analysis, the test served a crucial purpose: to examine whether repeated exposure to the same target words in different conditions had resulted in any implicit learning effects. Including this recognition task added a layer of methodological rigour by allowing the researcher to

assess whether familiarity with target items increased over time—a possibility that could influence reaction time or accuracy.

3.4.3. Data Cleaning

All data extracted from the eye tracker were exported as .txt and Excel files. Event statistics for each trial, AOI-related data, and raw gaze samples were obtained from the eye-tracking software. These outputs included a wide range of measures: fixation duration, minimum and maximum fixation duration, saccade duration, minimum and maximum saccade duration, saccade amplitude, number of blinks, gaze duration, pupil size, and other eye-movement indices. AOI (Area of Interest) files were also generated to isolate fixations and saccades that fell within the regions corresponding to primes and target verbs.

Before analysis, the eye-tracking data were pre-processed and cleaned. As is standard in eye-tracking research, extremely short or extremely long fixations were excluded to avoid artefacts (Godfroid, 2020). In this study, fixations shorter than 80 ms were removed from the dataset, as such, very brief fixations are unlikely to reflect meaningful linguistic processing. Very long fixations (above the upper cutoff used in the software) were also inspected and treated as potential outliers. These were not automatically discarded, but reviewed individually in order to determine whether they represented genuine cognitive engagement or technical irregularities.

In addition to fixation duration filters, raw gaze paths were visually inspected for calibration drift or gaze scatter, which may indicate poor calibration or participant fatigue. Trials with excessive data loss, track loss, or blink artifacts during key stimulus presentation windows were marked for exclusion. Eye-tracking accuracy and precision were also checked per participant to ensure that the system had captured gaze behaviour reliably across trials. Importantly, data quality for each participant was evaluated holistically by considering several factors, including the number of usable fixations, total gaze time, and alignment with AOIs.

As a result of these quality control steps, one participant (Participant 1) was excluded from all analyses because their eye-movement recording was clearly unreliable. This

participant's data contained very few valid fixations, irregular gaze patterns, and signs of inattention (e.g., multiple trials with missing AOI data or gaze completely offscreen). Their inclusion would have introduced noise and weakened the reliability of statistical comparisons.

After cleaning, the remaining eye-movement data were aggregated at the trial level and merged with the behavioural data (reaction time and accuracy). For each participant and each trial, summary measures such as first fixation duration, fixation count, total fixation duration, and glance duration were calculated within the AOI corresponding to the target word. These values were then exported to Excel for further organisation and subsequently imported into statistical software (SPSS) for descriptive and inferential analyses. Merging behavioural and eye-tracking datasets enabled a more comprehensive understanding of participant responses, allowing for condition-level comparisons and correlation analyses between attention metrics and task performance.

3.4.4. Data Analysis

To address the research questions of this study, both descriptive and inferential statistical procedures were applied to the data collected from the lexical decision task, eye-tracking metrics, and accompanying participant information. All Likert-scale responses, language background details, and vocabulary post-recognition test scores were first entered into Microsoft Excel for initial summarisation. Descriptive statistics such as means and standard deviations were computed to provide an overview of general trends in participant characteristics, familiarity with phrasal verbs, and potential vocabulary learning effects following the task.

The eye-tracking data were extracted from the SMI BeGaze software and organized in Excel spreadsheets, where each row represented a single trial. These files included columns for participant ID, trial number, prime–target condition, reaction time, accuracy, and fixation metrics (first fixation duration, fixation count, total fixation duration, and glance duration). Careful data cleaning was conducted to identify and remove trials with missing or invalid eye-tracking data due to blinks, loss of calibration, or tracking failures. Because the presentation of target items was counterbalanced

across participants, all data were checked for consistency and then merged into a single master dataset. In this master file, each trial was aligned with its corresponding experimental condition to ensure accurate within-subject comparisons.

To facilitate the statistical analysis, the five prime–target conditions were coded numerically as follows: related prime-target pairs, unrelated pairs, neutrals, pseudo pairs, and fillers. This coding system enabled efficient filtering, sorting, and condition wise comparison for both behavioural and fixation-based measures.

Descriptive statistics were calculated for all major dependent variables across the five experimental conditions. These included reaction time, accuracy, and the four fixation metrics. These descriptive analyses provided a foundational understanding of the general distribution, variability, and trends in the data, and were useful for visualizations and initial interpretation.

Following this, inferential statistical analyses were performed to evaluate the effects of experimental condition on each dependent variable. Repeated-measures analyses of variance (ANOVAs) were conducted to assess whether differences between conditions were statistically significant for each behavioural and eye-tracking measure. To ensure the validity of these tests, Mauchly’s test of sphericity was applied in each case. When the assumption of sphericity was violated, the Greenhouse–Geisser correction was used to adjust the degrees of freedom, providing a more accurate estimate of significance levels.

Post-hoc comparisons using the Least Significant Difference (LSD) method were conducted to identify where significant differences occurred between specific conditions. This allowed the researcher to determine, for example, whether related primes led to significantly faster reaction times than unrelated or filler primes. In addition to these comparisons, Pearson correlation analyses were carried out to examine the relationships between fixation behaviours (e.g., fixation count or duration) and reaction times. These analyses were conducted both across all conditions and within each condition separately to explore potential condition-specific trends.

To wrap up, the combination of descriptive summaries and inferential testing provided a comprehensive framework for answering the study's research questions. The analysis allowed for the examination of how prime–target relationships influenced attentional patterns and processing speed, and how these effects interacted with task performance and implicit versus explicit processing strategies.

Chapter 4. Results and Discussions

This chapter presents the results of the study, which examined how attentional patterns unfold during the processing of phrasal verbs using a lexical decision task (LDT) supported by eye-tracking data. The study explored how different prime–target relationships—namely, related, unrelated, neutral, pseudoword, and filler conditions—affect both visual attention and task performance in second language readers.

The analysis focused on fixation-based eye-tracking metrics—including first fixation duration, fixation count, total fixation duration, and glance duration—alongside behavioural measures such as reaction time and accuracy. These measures were chosen to provide insight into how semantic and structural relationships between primes and targets influence the cognitive processing demands of lexical decisions.

The results address three interrelated aims. First, the study examined how semantic congruency and lexical familiarity affect fixation behaviour, shedding light on how attention is allocated during word recognition. Second, it explored the relationship between eye movement patterns and reaction time, offering a window into the efficiency and automaticity of lexical processing. Third, it interpreted differences in performance across conditions in terms of implicit and explicit processing strategies: conditions that enabled fast, accurate responses were associated with automatic, implicit mechanisms, while slower and more effortful responses suggested engagement of controlled, explicit processes.

The chapter begins with descriptive statistics summarizing performance and eye tracking metrics across all conditions, providing an overview of central tendencies and variability.

This is followed by inferential analyses, including Mauchly's test of sphericity, repeated measures ANOVAs, and, where necessary, Greenhouse-Geisser corrections. Post-hoc comparisons are used to identify specific condition effects. Together, these findings offer a detailed account of how phrasal verb processing unfolds under varying priming

conditions, and how attentional and behavioural data intersect to reveal the underlying cognitive mechanisms at play.

4.1. Descriptive Statistics:

In this part statistics related to participants, and their background English knowledge is demonstrated. Also, mean, and standard deviation for five conditions (related, unrelated, pseudo, neutral, fillers) in First fixation duration, Fixation count, total fixation time, and Glance duration have been shown in Table 3.

4.1.1. Frequency distribution of the participant

The participants in this experiment are summarized by age and degree:

Table 3 Frequency Distribution of the Research Sample by Gender, Age, and Education Level

Category	Frequency	Percentage
Gender		
Male	10	33.3%
Female	20	66.7%
Age Group		
Under 30 years	15	50.0%
30 to 35 years	9	30.0%
Over 35 years	6	20.0%
Education Level		
Bachelor	16	53.3%
Master	12	40.0%
PhD	2	6.7%
Total	30	100.0%

According to Table 3, most of the participants (66.7%) were female. Considering the age of the participants, half of the participants (50.0%) were under 30 years old, while only 20.0% were over 35. In terms of their education level, most participants (53.3%) had a bachelor's degree, while 40.0% had a master's degree and 6.7% held a PhD.

4.1.2. Description of Fixation Metrics

Mean of fixation metrics (First fixation duration, Fixation count, total fixation duration, and glance duration in different conditions of prime-target pairs (related, unrelated, pseudo, neutral, and fillers) categorized in Table 4, followed by bar tables which pertain to each other respectively.

Table 4 Descriptive Statistics of First Fixation Duration, Fixation Count, Total Fixation Duration, and Glance Duration in Different Conditions of the Prime-target Pairs

Condition	Measure	Mean	SD
Related Prime/Target	First Fixation Duration	441.33	123.23
	Fixation Count	0.94	0.30
	Total Fixation Duration	437.17	127.57
	Glance Duration	440.85	123.77
Unrelated Prime/Target	First Fixation Duration	435.20	133.65
	Fixation Count	0.92	0.32
	Total Fixation Duration	428.75	139.88
	Glance Duration	431.74	137.29
Pseudo Words	First Fixation Duration	442.68	121.68
	Fixation Count	0.94	0.27
	Total Fixation Duration	440.79	122.39
Neutral	Glance Duration	442.92	120.18
	First Fixation Duration	450.76	108.37

	Fixation Count	0.97	0.26
	Total Fixation Duration	447.98	110.90
	Glance Duration	451.05	106.68
Fillers	First Fixation Duration	441.88	117.51
	Fixation Count	0.99	0.32
	Total Fixation Duration	448.59	110.10
	Glance Duration	452.65	106.98

Table 4 summarises the descriptive statistics for first fixation duration, fixation count, total fixation duration, and glance duration across the five prime–target conditions. Overall, the means for first fixation duration and total fixation duration are broadly similar across conditions, clustering around 430–450 ms. Neutral and filler conditions tend to show slightly longer first fixation durations (450.76 ms and 441.89 ms, respectively) and total fixation durations (447.98 ms and 448.59 ms) than the related and unrelated prime conditions, which suggests a modest increase in processing time when the prime is neutral or when the item functions as a filler.

A similar pattern can be seen in the fixation count data. Fixation counts are lowest for unrelated primes ($M = 0.929$) and related primes ($M = 0.948$), slightly higher for pseudo words ($M = 0.945$) and neutral items ($M = 0.970$), and highest for fillers ($M = 0.995$). This indicates that participants tended to make marginally more fixations on neutral and filler items than on related or unrelated prime–target pairs. Glance durations also follow this trend, with the lowest mean values for unrelated primes (431.75 ms) and the highest for fillers (452.66 ms), again suggesting somewhat more sustained processing of filler items.

Standard deviations are relatively similar across conditions for all measures, indicating comparable variability in eye-movement behaviour regardless of prime–target type. These descriptive patterns already hint that prime–target relationships may influence attention allocation, with neutral and filler items generally associated with slightly longer and more numerous fixations. The inferential analyses reported in the following sections test whether these differences are statistically reliable.

Figure 6 illustrates the mean first fixation duration across the five prime–target conditions as an example. The corresponding figures for the other fixation measures are provided in the Appendix.

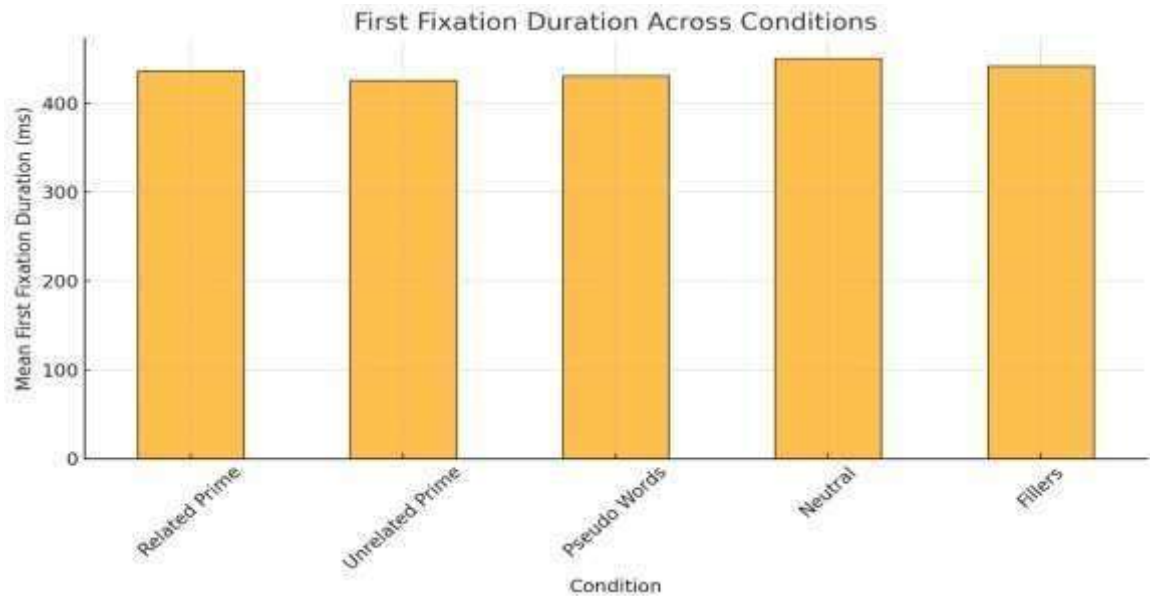


Figure 6 Mean of first fixation duration across experimental conditions.

4.1.3. Descriptive statistics of saccades

Saccade measures were analyzed, and no significant effects of condition were found. Nevertheless, descriptive statistics are reported to provide a complete picture of eye movement behaviour across the five prime–target conditions, to document the absence of large differences in the saccade measures, and to allow comparison with previous and future eye-tracking studies. Table 5 summarizes the mean and standard deviation for saccade count, saccade duration, saccade velocity, and saccade amplitude in each condition.

Table 5 Descriptive Statistics for Saccade Measures across the Five Prime–target Conditions

Condition	Saccade count M (SD)	Saccade duration (ms) M (SD)	Saccade velocity (°/s) M (SD)	Saccade amplitude (°) M (SD)
Related	0.9276 (0.25925)	31.6758 (7.35688)	4.0030 (24.06015)	0.1248 (0.79743)
Unrelated	0.9362 (0.24445)	31.7767 (7.44253)	3.9756 (24.53802)	0.1091 (0.49428)
Pseudo	0.9356 (0.24548)	32.1230 (7.33096)	3.5140 (24.22429)	0.1111 (0.81199)
Neutral	0.9420 (0.23390)	31.4208 (7.62180)	3.0970 (6.79507)	0.0941 (0.23644)
Filler	0.9322 (0.25150)	31.5804 (7.41635)	3.8217 (22.45865)	0.1165 (0.74454)

Table 5 summarises the saccade measures across the five prime–target conditions. Descriptively, the neutral condition shows the highest mean saccade count, the shortest saccade durations, and the lowest saccade velocities, which may point to relatively simpler or less cognitively demanding processing. In contrast, the pseudo condition has the longest saccade durations, which could reflect slightly greater processing effort. The related condition also shows some indications of more active or exploratory eye movements (e.g., relatively higher velocity and larger amplitude).

However, as shown in Table 6, none of these differences are statistically significant for any of the saccade metrics (saccade count, duration, velocity, or amplitude), with all p-values exceeding .05. Thus, while the descriptive statistics suggest small variations across conditions, there is no evidence of reliable condition effects on saccadic behaviour in this dataset.

Table 6 ANOVA Test Results of Saccade Metrics in Five Different Conditions

	F-Statistic	p-Value
Saccade_Count_Mean	1.1248443310022649	0.3471542363155489
Duration_Mean	0.4283170129083265	0.7880056256159025
Velocity_Mean	1.145334444946205	0.33767000953737036

Amplitude_Mean	0.08542474316063349	0.9868254853245965
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In summary, none of the saccade measures differed significantly across conditions, so the following sections focus on fixation-based metrics to address the research questions.

4.2. Inferential Statistics

This study focused on answering three questions, the first one is:

1. 2. 1. Research Question 1:

How do different prime-target relationships (related, unrelated, pseudo, neutral, fillers) influence fixation metrics (first fixation duration, fixation count, total fixation duration) during the processing of phrasal verbs?

To address the first research question, Mauchly's test of sphericity is first applied to determine whether the assumption of sphericity is met for each fixation metric. For metrics where this assumption is violated, the Greenhouse-Geisser correction is used to adjust the degrees of freedom, ensuring accurate statistical inference. Subsequently, a repeated measures ANOVA is performed to examine within-subject differences in fixation metrics (first fixation duration, fixation count, and total fixation duration) across the five prime target conditions. Post-hoc pairwise comparisons are conducted to identify significant contrasts between conditions. These analyses aim to provide a detailed understanding of how prime-target relationships influence attention allocation during phrasal verb recognition.

Mauchly's test results are summarized in Table 7. For all fixation metrics—first fixation duration, fixation count, fixation time, and glance duration—the p-values were below .001, indicating significant violations of the sphericity assumption. In other words, the variances of the differences between conditions were not equal for any of the four metrics. Because sphericity was violated for all measures, the Greenhouse-Geisser correction was applied in the subsequent repeated-measures ANOVAs.

Table 7 Mauchly's Test for Sphericity in Five Prime-target Conditions (related, unrelated, pseudo words, neutral, fillers) for Various Fixation Metrics

Test Statistic	Chi-Square Value	Degrees of Freedom	p-Value	Sphericity Result	Condition
0.940	106.906	9	0.001	Violation	First Fixation Duration
0.930	51.962	9	0.001	Violation	Fixation Count
0.872	98.475	9	0.001	Violation	Fixation Time
0.857	111.013	9	0.001	Violation	Glance Duration

Due to the rejection of the sphericity assumption, the final analysis for group comparisons will employ the Greenhouse-Geisser correction. This method helps to adjust the ANOVA results, providing greater accuracy in assessing the mean differences among the groups present here to readers.

Table 8 Results of Repeated Measures ANOVA for First Fixation Duration across the Five Prime-target Conditions (related, unrelated, pseudo words, neutral, fillers), (Greenhouse-Geisser Corrected)

Source of Variation	Sum of Squares	Degrees of Freedom (df)	Mean Squares	F-Statistic (F)	p-Value (Sig)	Test Power
Factor (Condition)	214,322.659	3.873	53,580.665	6.941	0.001	0.994
Error	53,693,410.980	6,734.886	7,972.430	-	-	-
Total	53,907,733.640	6,738.759	-	-	-	-

The Greenhouse–Geisser–corrected repeated-measures ANOVA for first fixation duration across the five prime–target conditions is presented in Table 8. As shown in the table, the effect of condition on first fixation duration was statistically significant ($p = .001$). The high test power (0.994) suggests that the analysis had a strong ability to detect true differences between conditions. To determine which conditions differed from one another, LSD post hoc pairwise comparisons were carried out (Table 9).

Table 9 LSD Post-hoc Pairwise Comparisons for First Fixation Duration

Comparison	p-Value	Observation
Related Prime vs. Unrelated Prime	0.033	Unrelated Primes had shorter first fixation durations.
Related Prime vs. Neutral	0.002	Neutral Conditions required longer fixation durations.
Unrelated Prime vs. Pseudo Words	0.017	Pseudo Words had longer fixation durations.
Unrelated Prime vs. Neutral	0.001	Neutral Conditions had longer fixation durations.
Unrelated Prime vs. Fillers	0.040	Fillers required longer fixation durations.
Pseudo Words vs. Neutral	0.004	Neutral Conditions had longer fixation durations.
Neutral vs. Fillers	0.002	Neutral Conditions required longer fixation durations.

Overall, unrelated primes produced shorter first fixation durations than most other conditions, suggesting that participants could quickly dismiss prime–target pairs that lacked a meaningful semantic relationship. Neutral primes (e.g., identical prime–target pairs such as *chew–chew*) showed the longest first fixation durations, which may reflect greater ambiguity and higher processing demands. Pseudo-word primes also led to longer first fixations than unrelated primes, presumably due to the ambiguity of the pseudo forms. Related primes facilitated processing relative to some other conditions but still showed slightly longer first fixation durations than unrelated primes, which may indicate deeper semantic engagement when the prime and target are meaningfully connected.

This pattern of fast initial disengagement for unrelated primes aligns with previous research showing that non-semantic stimuli can be dismissed rapidly (Wisintainer & Mota, 2018).

Interestingly, while related primes showed slightly longer initial fixations, this may reflect semantic engagement rather than confusion—a finding consistent with Sprenger et al.’s (2006) model where early compositional parsing precedes holistic recognition. A repeated-measures ANOVA with Greenhouse–Geisser correction was also conducted for total fixation time across the five prime–target conditions (Table 10). The analysis revealed a significant main effect of condition on fixation time ($p = .001$), confirming that total fixation time differed across the five prime–target relationships. LSD post-hoc comparisons are reported in Table 11.

Table 10 Results of Repeated Measures ANOVA for Fixation Time across the Five Prime-target Conditions (related, unrelated, pseudo words, neutral, fillers), (Greenhouse-Geisser Corrected)

Source of Variation	Sum of Squares	Degrees of Freedom	Mean Squares	F-Statistic	pvalue	Power of Test
Factor	194,635.738	3	51,587.092	6.218	0.001	0.986
Error	22,500,502.84	2,712	8,295.998			
Total	22,699,638.58	2,716				

According to Table 10, p-value is 0.001, which is below the 0.05 threshold and confirms the significant difference of fixation time in five different conditions. An LSD test was conducted and the results are depicted in Table 11.

Table 11 LSD Post-hoc Pairwise Comparisons for Fixation Time

Comparison	p-value
Related Prime vs. Unrelated Prime	0.081
Related Prime vs. Pseudo Words	0.461
Related Prime vs. Neutral	0.030
Related Prime vs. Fillers	0.007
Unrelated Prime vs. Pseudo Words	0.012
Unrelated Prime vs. Neutral	0.001
Unrelated Prime vs. Fillers	0.001
Pseudo Words vs. Neutral	0.120
Pseudo Words vs. Fillers	0.883

Neutral vs. Fillers	0.056
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A comparison of the results for first fixation duration and total fixation time shows an interesting pattern. For first fixation duration, unrelated primes led to shorter initial fixations, suggesting that participants quickly disengaged when there was no apparent semantic link between prime and target. In contrast, total fixation time tended to be longer for unrelated prime–target pairs, indicating that, although the initial fixation was brief, participants required more time overall to process these items. Neutral conditions generally required longer fixations in both measures, consistent with greater processing effort. Taken together, these findings suggest that participants quickly reject unrelated primes at the initial stage of processing, but then need more cognitive effort to deal with them over the entire viewing period, whereas neutral and pseudo conditions seem to require sustained processing right from the start.

This dual pattern—short first fixations but longer total times for unrelated conditions—could indicate a two-stage process: initial rejection followed by uncertainty-driven re-evaluation. This aligns with findings from Conklin & Schmitt (2012), where L2 learners initially discard irrelevant input but later expend more effort verifying their decision.

Table 12 Results of Repeated Measures ANOVA for Fixation Counts across the Five Prime-target Conditions (related, unrelated, pseudo words, neutral, fillers), (Greenhouse-Geisser Corrected)

Source	F-statistic	p-value
Conditions	7.442	0.001

According to Table 12, the p-value ($p = .001$) indicates a statistically significant difference in fixation counts across the five conditions (related prime, unrelated prime, pseudo words, neutral, and fillers). To identify which pairs of conditions differed from one another, LSD post-hoc comparisons were conducted. The results are summarized in Table 13.

Table 13 LSD Post-hoc Test Results for Pairwise Comparisons of Fixation Counts

Condition Comparison	Mean Difference	p-value	Significance
Fillers vs. Neutral	0.057	0.002	Yes
Fillers vs. Pseudo Words	0.048	0.001	Yes

Fillers vs. Related Prime	0.052	0.001	Yes
Fillers vs. Unrelated Prime	0.062	0.001	Yes
Neutral vs. Pseudo Words	0.009	0.136	No
Neutral vs. Related Prime	0.005	0.081	No
Neutral vs. Unrelated Prime	0.019	0.002	Yes
Pseudo Words vs. Related Prime	0.004	0.816	No
Pseudo Words vs. Unrelated Prime	0.019	0.201	No
Related Prime vs. Unrelated Prime	0.023	0.136	No

Considering the mean differences, the repeated-measures ANOVA, and the LSD post-hoc tests for fixation counts, the results show that fillers have a significantly higher fixation count than all other conditions. This is confirmed by the larger mean for fillers and by significant p-values in all comparisons involving fillers. In addition, neutral primes yield slightly higher fixation counts than unrelated primes, and this difference is also statistically significant ($p = .002$). In contrast, no significant differences were found between pseudo words and related or unrelated primes, which is consistent with their similar means and suggests no notable variation in attention allocation among these three conditions. Likewise, the lack of a significant difference between related and unrelated primes indicates that the semantic relationship alone does not substantially affect the number of fixations.

The elevated fixation count in the filler condition likely reflects processing disruption, rather than elaboration. Unlike pseudowords—which may trigger cautious, controlled checking (Angele et al., 2015)—fillers offer no predictable structure or meaning, leading to hesitation and increased gaze shifts as participants attempt to resolve their unfamiliarity. This echoes Kretzschmar et al. (2020), who found that semantically inconsistent primes overload working memory, especially in L2 contexts.

Table 14 Results of Repeated Measures ANOVA for Glance Duration across the Five Prime-target Conditions (related, unrelated, pseudo words, neutral, fillers), (Greenhouse Geisser Corrected)

Source of Variation	Sum of Squares	Degrees of Freedom (df)	Mean Squares	F-Statistic	p-Value	Power
Factor	205,681.580	3.754	54,784.204	6.685	0.001	0.991

Error	22,120,282.550	2,699.411	8,194.486			
Total	22,325,964.130	2,703.165				

Table 14 presents the Greenhouse–Geisser–corrected repeated-measures ANOVA for glance duration across the five prime–target conditions. The analysis revealed a significant main effect of condition on glance duration, $F(3.754, 2699.411) = 6.685$, $p = .001$, $\eta^2 \approx .05$.

This indicates that the time spent glancing at target words varied systematically across the related, unrelated, pseudo, neutral, and filler conditions. The high statistical power (0.991) suggests that the test was sensitive enough to detect true differences between conditions. LSD post-hoc tests were conducted to examine pairwise differences in glance duration, and the results are summarized in Table 15.

Table 15 LSD Post-hoc Test Results for Pairwise Comparisons of Glance Duration

Comparison	p-Value
Related Prime vs. Unrelated Prime	0.061
Related Prime vs. Pseudo Words	0.668
Related Prime vs. Neutral	0.038
Related Prime vs. Fillers	0.003
Unrelated Prime vs. Pseudo Words	0.021
Unrelated Prime vs. Neutral	0.001
Unrelated Prime vs. Fillers	0.001
Pseudo Words vs. Neutral	0.077
Pseudo Words vs. Fillers	0.014
Neutral vs. Fillers	0.702

The post-hoc results show several significant pairwise differences. Glance durations for related primes were shorter than for neutral conditions ($p = .038$) and fillers ($p = .003$), indicating more efficient processing when the prime and target were semantically related. Unrelated primes differed significantly from pseudo words ($p = .021$), neutral conditions ($p = .001$), and fillers ($p = .001$), suggesting that the absence of a meaningful

prime–target link leads to longer overall viewing than in some other conditions. Pseudo words and fillers also differed significantly ($p = .014$), with fillers eliciting longer glances. Other comparisons, such as related versus unrelated primes ($p = .061$) and pseudo words versus neutral conditions ($p = .077$), did not reach statistical significance.

Taken together, these findings indicate that glance duration is generally shortest for related primes, consistent with relatively efficient, facilitated processing. Fillers tend to show the longest glance durations, reflecting more effortful processing. Neutral and pseudo conditions fall between these extremes, requiring more attention than related primes but often less than fillers. This pattern is in line with the other fixation measures, where fillers and unrelated primes also attracted higher fixation counts and longer fixation times, while related primes showed evidence of more efficient processing. The data reveals that Glance Duration is shortest for related primes, indicating efficient, implicit processing.

Null Hypothesis (H_{01})

The prime–target relationship does not significantly influence fixation metrics (first fixation duration, fixation count, and total fixation duration) during target word processing.

The analyses for Research Question 1 showed significant effects of prime–target relationships on multiple fixation metrics ($p < .05$). Neutral and pseudo conditions generally required longer fixation durations, reflecting increased cognitive effort, whereas unrelated primes produced shorter first fixations, suggesting that irrelevant prime–target pairs were quickly dismissed. Related primes facilitated more efficient processing, with relatively short fixations compared to other conditions. Fixation counts were highest for fillers, indicating extended attention allocation, and glance duration analyses similarly revealed shorter glances for related primes and longer ones for fillers and unrelated primes. Together, these results confirm that prime–target relationships significantly influence attention allocation during word processing. Therefore, the null hypothesis (H_{01}) is rejected.

4. 2. 2. Research Question 2:

What is the relationship between fixation metrics (first fixation duration, fixation count, and total fixation duration) and reaction time during the lexical decision task across prime-target conditions?

After cleaning the data by removing missing values, fixation metrics were categorized in different condition pairs. To investigate research question 2, we conducted the correlation analysis between reaction time and fixation duration total as well as first fixation duration across different prime-target conditions: related prime, unrelated prime, pseudo words, neutral, and fill. To assess the strength and direction of relationships between fixation metrics and reaction time, Pearson's correlation coefficients were computed. Table 16, shows the results of the correlation between fixation metrics and reaction time. As it demonstrates, there is a weak correlation between first fixation and reaction time, also total fixation duration and reaction time. Fixation time and reaction time didn't show a significant relationship. Although it is natural because according to data of eye fixation behaviors, fixation count in most target trials was reported 1, and only in some cases were two fixation counts reported.

Table 16 Correlation between Fixation Metrics and Reaction Time

Variable Pairs	Pearson's	-value	Interpretation
Fixation Count vs. Reaction Time	-0.0045	0.700	No significant relationship
Total Fixation Duration vs. Reaction Time	-0.0417	0.0003	Very weak negative correlation (significant)
First Fixation Duration vs. Reaction Time	-0.0403	0.0005	Very weak negative correlation (significant)

Table 16 shows the correlations between fixation metrics and reaction time. There was no significant relationship between fixation count and reaction time ($r = -.0045$, $p = .700$). Total fixation duration and first fixation duration both showed very weak negative correlations with reaction time ($r = -.0417$, $p = .0003$; $r = -.0403$, $p = .0005$, respectively). Although these two correlations are statistically significant, their effect

sizes are extremely small, indicating that fixation durations are only minimally related to reaction times in this dataset. Additional scatterplots illustrating these relationships are provided in Appendix F. Table 17 depicts the different conditions of prime target pairs and their correlations with first fixation duration, total fixation duration, and reaction time.

Table 17 Correlation between Fixation Metrics and Reaction Time in Different Conditions of Prime-target pairs

Condition	Variable	Fixation Duration Total	First Fixation Duration
Related Prime	Reaction Time	-0.060	-0.045
	First Fixation Duration	0.694	
Unrelated Prime	Reaction Time	-0.071	-0.068
	First Fixation Duration	0.631	
Pseudo Words	Reaction Time	-0.005	-0.020
	First Fixation Duration	0.640	
Neutral	Reaction Time	-0.022	0.013
	First Fixation Duration	0.662	
Fill	Reaction Time	-0.053	-0.074
	First Fixation Duration	0.692	

Pearson's correlations showed small but statistically significant negative relationships between total fixation duration and reaction time in the related prime ($r = -.060$, $p < .05$), unrelated prime ($r = -.071$, $p < .01$), and filler ($r = -.053$, $p < .05$) conditions. In these conditions, longer total fixation durations were associated with slightly faster responses, although the effect sizes are very weak. No significant correlations were found in the pseudo and neutral conditions, suggesting that fixation duration does not reliably predict reaction time there.

A similar pattern emerged for first fixation duration. Significant negative correlations with reaction time were observed only in the unrelated prime ($r = -.068$, $p < .01$) and

filler ($r = -.074$, $p < .01$) conditions, indicating that longer initial fixations were linked to somewhat faster responses in these specific contexts. In the related, pseudo, and neutral conditions, the correlations were not significant, implying that first fixation duration played a limited role in decision speed outside these particular conditions.

Across all conditions, total fixation duration and first fixation duration were strongly and positively correlated, indicating stable fixation behaviour: participants who spent longer on their first fixation also tended to have longer total fixation times. Overall, the correlation analysis suggests that fixation duration can be related to faster reaction times, but only in certain prime–target conditions (especially unrelated and filler). In pseudo and neutral conditions, fixation duration does not appear to meaningfully influence response speed.

Figure 7 shows the distribution of reaction times across the five prime–target conditions. The “Psd” (pseudo) and “filler” conditions tend to have higher median reaction times than the “neutral,” “related,” and “unrelated” conditions. All conditions show some extreme values in the upper range, which likely represent outliers. The pseudo and filler conditions also have a wider interquartile range, indicating greater variability in reaction time.

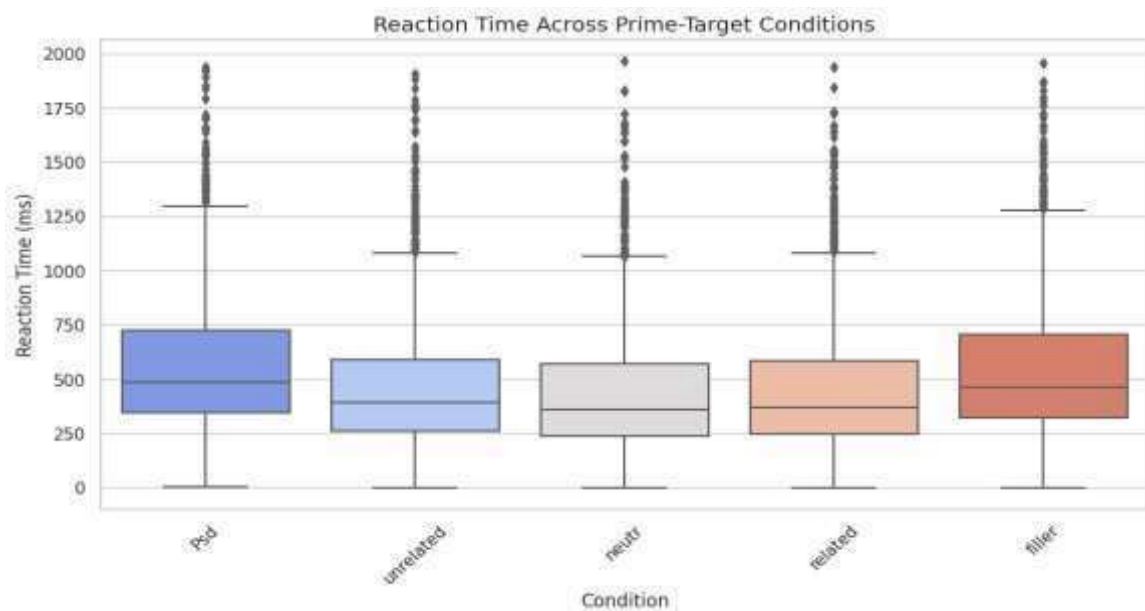


Figure 7 Boxplots of reaction time across the five prime–target conditions. Pseudo and filler conditions tend to show higher median reaction times and greater variability than the other conditions, indicating slower and more variable responses.

In summary, fixation duration metrics influence reaction time only in certain prime target conditions. Longer total fixation duration is associated with shorter reaction times in related prime, unrelated prime, and fill conditions, but no significant relationship is found in pseudo words and neutral conditions. Similarly, longer first fixation duration is linked to shorter reaction times in unrelated prime and fill conditions, but not in other conditions. Additionally, fixation duration total and first fixation duration are consistently positively correlated across all conditions, indicating stable visual processing patterns. These results suggest that longer fixations may aid in faster decision-making under specific conditions, particularly when words are related or when lexical processing demands are higher.

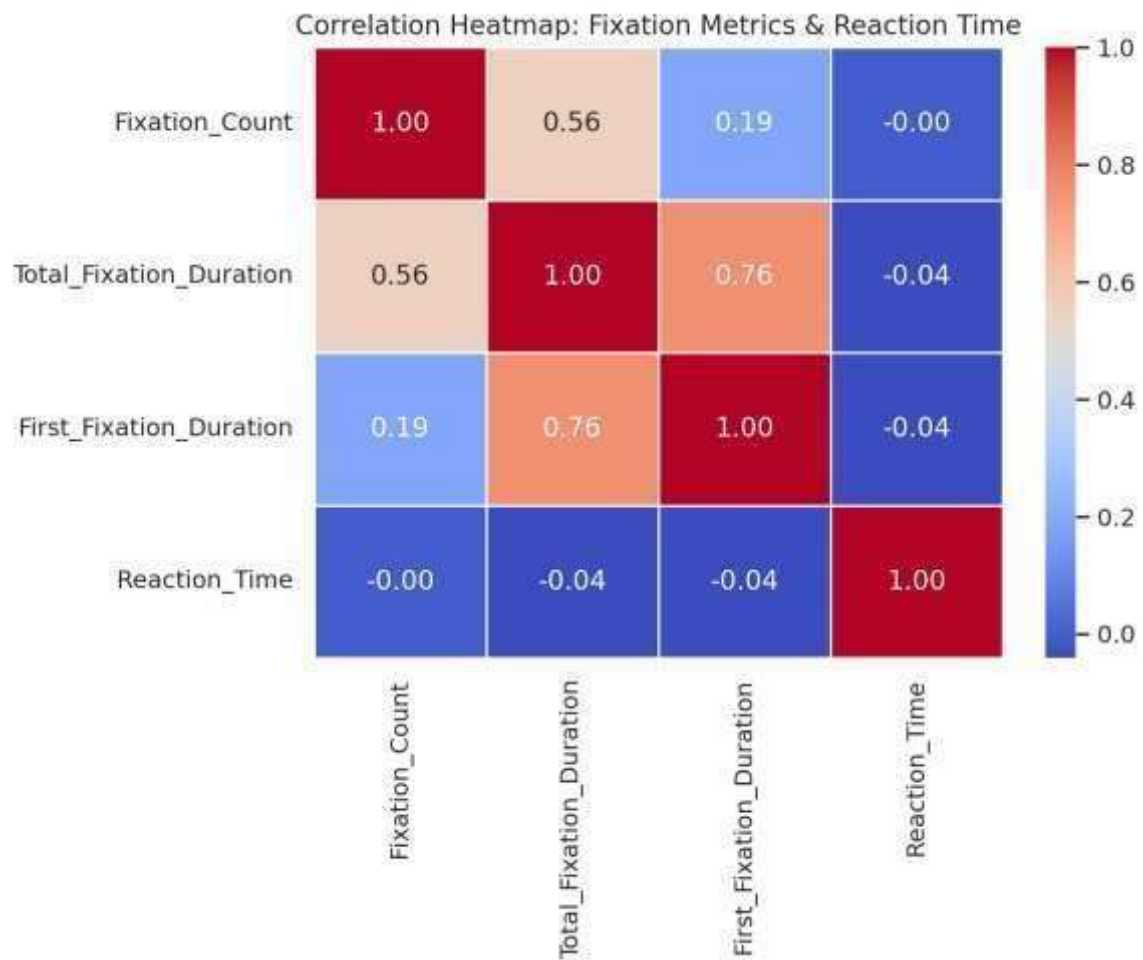


Figure 8 Correlation heatmap between fixation metrics and reaction time.

Figure 8 shows a correlation heatmap for fixation count, total fixation duration, first fixation duration, and reaction time. The warm colours in the upper-left part of the matrix indicate moderate to strong positive correlations among the fixation measures

themselves (e.g., total and first fixation duration, $r \approx .76$; fixation count and total fixation duration, $r \approx .56$). In contrast, all correlations between the fixation metrics and reaction time are close to zero (around $-.00$ to $-.04$), confirming that, overall, reaction time is essentially independent of these eye-movement measures.

The null hypothesis (H_{02}) stated that there is no significant relationship between fixation metrics and reaction time across prime–target conditions. However, the condition specific analyses showed small but statistically significant negative correlations between total fixation duration and reaction time in the related prime ($r = -.060$, $p < .05$), unrelated prime ($r = -.071$, $p < .01$), and filler ($r = -.053$, $p < .05$) conditions, and between first fixation duration and reaction time in the unrelated prime ($r = -.068$, $p < .01$) and filler ($r = -.074$, $p < .01$) conditions. No significant relationships were found in the pseudo or neutral conditions. Fixation count did not correlate significantly with reaction time in any condition, although total fixation duration and first fixation duration were positively correlated across all conditions, indicating stable fixation behaviour. Taken together, these findings mean that H_{02} is rejected: fixation duration metrics are related to reaction time in some conditions, but the effects are very small in size and clearly condition-dependent rather than universal.

4. 2. 3. Research Question 3:

As it is stated in chapter one, the third question of the study is:

How do prime-target conditions influence task performance (reaction time, and accuracy), and what do these metrics reveal about implicit vs. explicit processing?

This question investigates how prime-target relationships affect task performance, measured through reaction time (RT) and accuracy. These two metrics are key indicators of underlying cognitive mechanisms: faster, more automatic responses are associated with implicit processing, while slower, more deliberate responses reflect explicit processing.

To address this question of the thesis, firstly, all missing data (e.g., trials with unrecorded mouse clicks) were removed prior to analysis. Then, the reaction time data (ms) pertaining to each condition were considered. Accuracy was scored as a binary variable, where 1 indicated a correct response and 0 an incorrect one. The following table shows the descriptive statistics of reaction time in different conditions. Table 18 represents the descriptive statistics for reaction time and accuracy across prime target conditions.

Table 18 Mean Reaction Time and Accuracy by Prime–Target Condition

Condition	Mean RT (ms)	SD RT	Mean Accuracy	SD Accuracy
Psd	567.38	319.40	0.687	0.464
Filler	545.42	330.02	0.532	0.499
Neutral	439.79	315.14	0.657	0.475
Related	451.50	317.54	0.657	0.475
Unrelated	467.31	309.03	0.663	0.473

Table 18 summarizes mean reaction time and accuracy across the five prime–target conditions. Reaction times are fastest in the neutral and related conditions and slowest in the pseudoword and filler conditions. Accuracy is highest in the pseudoword condition and lowest in the filler condition, with related, unrelated, and neutral conditions showing similar, relatively high accuracy rates.

The interpretation of reaction time and accuracy in different conditions revealed conditions like neutral and related show faster reaction times compared to unrelated, which might suggest implicit facilitation. Accuracy also varies—Pseudo pairs and related ones are among the highest, which may reflect explicit recognition or stronger associations.

Based on the research question, two null hypotheses are expressed. The question investigates two dependent variables—reaction time and accuracy—both of which are used to infer whether the underlying cognitive processing is implicit or explicit. To address each variable clearly and allow for independent testing, the following null hypotheses are proposed:

H₀₁ (Reaction Time):

There is no significant difference in reaction time across prime target conditions.

H₀₂ (Accuracy):

There is no significant difference in accuracy across prime target conditions.

Table 18 presents the mean reaction times across the five prime–target conditions. Participants responded fastest in the neutral ($M = 439.79$ ms) and related ($M = 451.50$ ms) conditions, which suggests a facilitation effect, likely due to semantic or associative priming.

In contrast, the pseudoword ($M = 567.38$ ms) and filler ($M = 545.42$ ms) conditions elicited the slowest responses, indicating increased processing demands. The unrelated condition ($M = 467.31$ ms) fell between these extremes, reflecting moderate processing difficulty in the absence of a meaningful prime–target relationship. Overall, these differences support the view that prime–target relationships influence the efficiency of processing, particularly in terms of speed.

Table 18 also shows mean accuracy, defined as the proportion of correct responses, across the five experimental conditions. The pseudoword condition produced the highest accuracy ($M = 0.687$), suggesting that participants engaged in careful, deliberate processing when encountering unfamiliar but structured items. In contrast, the filler condition showed the lowest accuracy ($M = 0.532$), indicating greater uncertainty or guessing when there was no meaningful prime–target relationship. The remaining conditions—related ($M = 0.657$), unrelated ($M = 0.663$), and neutral ($M = 0.651$)—clustered around similar, relatively high accuracy rates, implying that participants generally responded reliably when prime–target pairs were familiar or semantically plausible.

In Figure 9, a dual-axis chart is used to illustrate the combined relationship between accuracy and reaction time across the five prime-target conditions. As shown in Figure 9, the blue bars represent mean accuracy (left y-axis), while the red line depicts mean reaction time (right y-axis). This format provides a clear and efficient comparison of processing speed and correctness within each condition. This chart provides a clear way to observe these two elements side by side and interpret processing speed and

correctness across conditions in a single view.

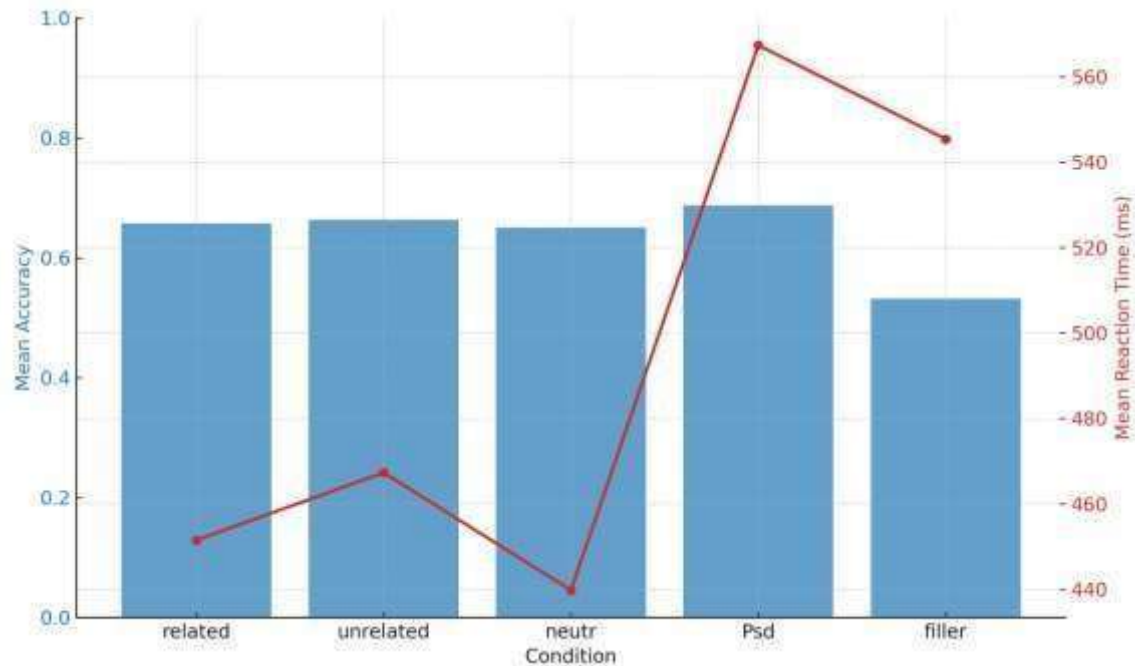


Figure 9 Combined accuracy and reaction time by condition.

The joined visualization of accuracy and reaction time across prime-target conditions provides a clear comparison of how these two metrics vary by stimulus type. The blue bars indicate mean accuracy, while the red line shows mean reaction time (RT) in milliseconds for each condition. Figure 9 reveals that neutral and related conditions were associated with the fastest response times, suggesting fluent processing facilitated by semantic or associative priming. At the same time, these conditions maintained moderately high accuracy, supporting the role of implicit processing. In contrast, the pseudoword (Psd) condition, while producing the slowest reaction times, yielded the highest accuracy of all conditions. This pattern implies that participants engaged in more deliberate, explicit processing when confronted with unfamiliar but structured stimuli.

The filler condition performed poorest on both metrics, exhibiting low accuracy and slower RTs, likely due to the lack of meaningful or predictable prime-target relationships. Unrelated condition fell in the middle, with slower RTs than related or neutral, but accuracy close to them. Overall, this figure highlights a trade-off between speed and accuracy depending on the cognitive demands of each condition. It supports the interpretation that implicit priming leads to faster and efficient responses in

related/neutral trials, whereas explicit effort is required in conditions like pseudowords or fillers.

To statistically support the descriptive trends, one-way ANOVAs were conducted for both reaction time and accuracy. The analysis revealed a significant effect of prime-target condition on reaction time, $F(4, 7450) = 49.88, p < .001$, indicating that the type of prime-target pairing influenced processing speed. To determine which specific condition pairs contributed to this significant effect, Fisher's LSD post hoc comparisons were conducted; Fisher's LSD post hoc comparisons showed that most condition pairs differed significantly, except for the pseudoword and filler conditions, which did not differ significantly in reaction time ($p = .063$). Neutral and related conditions produced significantly faster responses compared to pseudoword, unrelated, and filler conditions, suggesting processing facilitation in the presence of semantic or associative priming.

A separate one-way ANOVA also revealed a significant effect of condition on accuracy, $F(4, 8695) = 28.47, p < .001$. Similarly, post hoc analysis was performed to explore pairwise differences in accuracy across conditions. Post hoc tests indicated that the filler condition was significantly less accurate than all other conditions ($p < .001$ for most comparisons), while no significant accuracy differences were found between the pseudoword, related, and unrelated conditions. These findings confirm that prime-target condition influenced both response speed and accuracy, supporting the distinction between implicit facilitation in related and neutral conditions, and more effortful, explicit processing in filler and pseudoword trials. The results are shown in Table 19.

Table 19 Pairwise Comparisons of Reaction Time and Accuracy across Prime-target Conditions Using Fisher's LSD Test

Pairwise Comparison	Reaction Time	Accuracy
Psd vs. Related	☑ Significant ($p < .001$)	✗ Not significant
Psd vs. Neutral	☑ Significant ($p < .001$)	☑ Significant ($p = .021$)
Psd vs. Unrelated	☑ Significant ($p < .001$)	✗ Not significant
Psd vs. Filler	✗ Not significant ($p = .063$)	☑ Significant ($p < .001$)
Related vs. Neutral	✗ Not significant	✗ Not significant
Related vs. Unrelated	☑ Significant ($p < .001$)	✗ Not significant

Neutral vs. Unrelated	☒ Significant ($p < .001$)	☒ Not significant
Related vs. Filler	☒ Significant ($p < .001$)	☒ Significant ($p < .001$)
Unrelated vs. Filler	☒ Significant ($p < .001$)	☒ Significant ($p < .001$)
Neutral vs. Filler	☒ Significant ($p < .001$)	☒ Significant ($p < .001$)

These patterns align with the theoretical distinction between implicit and explicit processing. Implicit processing is typically fast, automatic, and unconscious, often triggered by familiar or semantically related stimuli. This is evident in the related suggesting they were able to process the target with minimal cognitive effort due to the presence of semantic priming. In contrast, explicit processing involves conscious, controlled, and effortful strategies, especially when stimuli are unfamiliar or lack meaningful context. This was reflected in the pseudoword condition, where participants slowed down but responded with greater accuracy, likely due to increased attention and deliberate evaluation. The filler condition, with both low accuracy and slower responses, likely imposed the highest cognitive load, as participants lacked both semantic cues and familiarity, requiring more effortful but less effective processing.

and neutral conditions, where participants responded more quickly and accurately

This interpretation is supported by the rejection of both null hypotheses, as summarized in Table 20. The table presents the hypotheses tested in relation to Research Question 3. Both hypotheses—concerning reaction time and accuracy—were statistically rejected based on the ANOVA results, confirming that prime-target condition significantly influenced task performance.

Table 20 Null Hypothesis Summary for Research Question 3

Hypothesis	Description	ANOVA Result	Conclusion
H ₀₁	No difference in reaction time across conditions	$F(4, 7450) = 49.88, p < .001$	☒ Rejected
H ₀₂	No difference in accuracy across conditions	$F(4, 8695) = 28.47, p < .001$	☒ Rejected

This confirms that prime-target condition had a statistically significant effect on both aspects of task performance, addressing the core aim of Research Question 3.

Overall, these results confirm that prime-target condition significantly influenced both the speed and accuracy of responses. The rejection of both null hypotheses supports the view that semantic and structural relationships between primes and targets modulate task performance. Faster and accurate responses in the related and neutral conditions are consistent with implicit processing, where priming facilitates automatic retrieval. In contrast, the slower but more accurate performance in the pseudoword condition—and the generally poor performance in the filler condition—suggest increased cognitive effort and explicit, deliberate processing. These findings set the stage for further interpretation in the next chapter, where the cognitive mechanisms underlying these effects are discussed.

4. 3. Summary of the Main Findings

This chapter presented the behavioural and eye-tracking results obtained from the lexical decision task, focusing on how different prime–target relationships affected participants’ processing patterns. Overall, participants performed the task with moderate to high accuracy across all conditions, indicating general task comprehension and reliability. Still, there were noticeable differences in how quickly and easily items were processed, depending on the type of prime–target pairing.

In terms of reaction time, responses were fastest in the neutral and related conditions. On the other hand, the pseudoword and filler conditions resulted in the slowest responses. This suggests that primes which either aided recognition through semantic or associative links (as in the related condition) or did not interfere with processing (as in the neutral condition) made it easier for participants to identify the target words quickly. Conversely, primes that were semantically incongruent or structurally unexpected disrupted processing, leading to slower reaction times.

Accuracy patterns showed a slightly different picture. The highest accuracy was observed in the pseudoword condition, likely due to participants adopting a more cautious, deliberate approach when the prime was clearly unfamiliar. The filler condition showed the lowest accuracy, while related, unrelated, and neutral conditions

fell somewhere in between, with relatively high but not exceptional scores. This divergence between speed and accuracy supports the idea that participants used different strategies in different conditions. While related and neutral primes allowed for quicker responses, the pseudoword condition prompted slower but more careful decisions.

Overall, the convergence of eye-tracking and behavioral data highlights the complex interplay between automatic and controlled processing mechanisms. Related and neutral primes promoted efficient recognition patterns consistent with implicit processing, while pseudoword and filler conditions triggered explicit strategies, including reanalysis and verification. These patterns lend empirical support to dual process models of lexical access in L2 (Evans, 2008; VanPatten & Smith, 2022).

The reaction time pattern observed in the present study—where neutral and related primes yielded the fastest responses, and pseudoword and filler primes produced the slowest—is broadly consistent with recent psycholinguistic research on semantic priming in lexical decision tasks (e.g., Anjum et al., 2019; Pan, 2020). In this respect, the faster reaction times in the related condition align well with previous findings showing that semantic relatedness between prime and target accelerates lexical access.

However, an important nuance in the present data is that neutral primes often produced reaction times comparable to, or even faster than, related primes. This pattern has also been noted in recent studies that emphasize the role of processing fluency and interference rather than semantic activation alone. For example, Hoedemaker and Gordon (2014) proved that primes that neither facilitate nor mislead processing can allow for smoother transitions to target recognition, particularly in tasks with time pressure. From this perspective, the neutral condition likely allowed faster responses because it didn't cause interference or require participants to resolve any complex meaning.

In contrast, the slowed reaction times observed in the pseudoword and filler conditions are in line with findings from studies showing that non-lexical or structurally

unexpected primes disrupt automatic processing and activate additional verification processes. Some research using lexical decision paradigms indicates that pseudowords often induce longer response times because participants engage in controlled checking strategies, even when accuracy remains high (e.g., Angele et al., 2015; Godfroid & Hui, 2025). This interpretation fits well with the present data, where pseudoword primes led to slow but accurate responses, suggesting deliberate decision-making rather than guessing.

At the same time, the filler condition showed both slow reaction times and low accuracy, distinguishing it from the pseudoword condition. This contrast mirrors findings in recent priming studies indicating that when primes are neither lexically valid nor systematically related to targets, they can create processing confusion rather than productive caution. Unlike pseudowords, which clearly signal a non-lexical status, filler items may lack clear processing cues, resulting in hesitation and increased error rates. Such patterns have been reported in studies examining disrupted or noisy priming environments, where incongruent primes interfere with lexical activation rather than simply slowing it (e.g., Pan, 2020).

Taken together, these comparisons suggest that the reaction-time effects observed in the present study are not only consistent with established semantic priming research but also contribute to a more nuanced understanding of how different types of primes shape processing efficiency. Specifically, the finding that neutral primes can rival or outperform related primes in reaction time highlights the importance of considering interference and processing fluency alongside semantic relatedness. This pattern supports recent arguments that lexical decision performance reflects an interaction between semantic activation, attentional control, and task-specific demands rather than a simple related–unrelated distinction.

In line with this, recent studies have increasingly emphasized the interplay between automaticity and control in lexical processing, especially in second language (L2) contexts. For example, Godfroid et al. (2018) argue that fixation behavior and response speed must be interpreted in light of task-specific expectations and the learner's familiarity with the input. In the present study, the pseudoword condition, although

eliciting slower responses, yielded the highest accuracy, likely reflecting more controlled, cautious processing strategies—a finding that supports this theoretical view. This echoes Yan et al. (2022), who reported that L2 readers tend to compensate for lexical uncertainty by increasing their processing effort when faced with unfamiliar or unpredictable stimuli.

Importantly, the neutral condition in this study seems to act as a "minimal interference" baseline, a concept discussed by Hoedemaker and Gordon (2014) and supported more recently by Williams & Rebuschat (2024). These works suggest that in the absence of semantic activation (as with related primes) or disruption (as with fillers), lexical processing may proceed more fluently due to reduced cognitive conflict. In this sense, the efficiency observed in the neutral condition may not indicate facilitation in the traditional semantic sense, but rather reflect a kind of processing economy—where the lack of semantic conflict reduces the need for additional resolution or inhibition.

On the other hand, the performance observed in the filler condition—both in terms of slowed responses and lower accuracy—points toward processing interference, rather than merely the absence of facilitation. This has been well-documented in studies examining lexical competition and semantic incongruity in priming paradigms. For instance, Kretzschmar et al. (2020) found that semantically inconsistent primes can overload working memory and introduce interference effects, especially in L2 contexts where lexical representations are less entrenched. This aligns with the present finding that filler primes—which offered no clear lexical or semantic cue—produced the least efficient and least accurate performance.

A deeper look at the eye-tracking data also reinforces these behavioral interpretations. First fixation durations and total fixation durations varied significantly by condition, with longer fixations observed in pseudoword and filler trials. This suggests that attentional allocation was sensitive to the semantic and lexical predictability of the prime–target pair. These results agree with Hu & Godfroid (2023), who found that L2 readers allocate more visual attention to unexpected or low-frequency stimuli, often as

a compensatory mechanism. The high fixation count and extended glance durations in the filler condition, in particular, point to prolonged engagement with the target word, likely due to the absence of cues supporting lexical prediction or integration.

Moreover, the present study adds support to the dual-process model of lexical processing (Evans, 2008; VanPatten & Smith, 2022), which posits that both implicit, fast-acting mechanisms and explicit, effortful strategies coexist in L2 learners' cognitive processing. The contrast between the quick, fluent responses in the related/neutral conditions and the slow but accurate performance in the pseudoword condition provides strong empirical support for this framework. Notably, this pattern echoes findings from Andreou and Gkantaki (2025), who reported that L2 learners switch between automatic and controlled processing depending on input predictability and task demands.

Another relevant aspect to consider is that semantic priming is not solely dependent on meaning overlap, but is also shaped by frequency, familiarity, and structural predictability. The findings of Schmid et al. (2017) suggest that when primes are familiar but do not create competition, learners can bypass deeper semantic processing through surface-level pattern recognition. This might explain why neutral primes, though semantically unrelated, sometimes produced reaction times as fast—or faster—than related ones in this study.

Interestingly, while much of the previous literature emphasizes the role of relatedness strength in shaping priming effects (e.g., Perea & Rosa, 2002), the present study suggests that interference avoidance may be equally influential. In particular, the lack of semantic or lexical conflict in neutral trials appears to enable efficient decision-making even in the absence of true facilitation. This has implications for how we conceptualize the role of neutral primes—not simply as “controls,” but as active contributors to processing dynamics under time-constrained decision tasks.

Finally, the current findings support calls in the literature (e.g., Godfroid, 2020; Stupina et al., 2018) to adopt multi-method approaches in L2 processing research. The

combination of reaction time data and fixation-based eye-tracking offers a more nuanced understanding of cognitive effort, allowing researchers to distinguish between conditions that merely slow responses and those that actively disrupt recognition and comprehension. The filler condition, in particular, illustrates how convergence between slow reaction times and increased visual attention signals genuine processing difficulty, not just caution or hesitation.

The eye-tracking measures provide a more detailed picture of how attention was allocated during target word processing. First fixation duration, total fixation duration, fixation count, and glance duration all showed significant effects of condition. In general, unrelated primes tended to produce shorter first fixations but sometimes longer overall fixation times, which may indicate that participants quickly recognised the lack of a meaningful link but still needed extra time to process the target. Neutral and pseudo conditions often showed longer fixation durations, suggesting that they required more cognitive effort, possibly because the prime gave little or ambiguous guidance. Fillers attracted the highest fixation counts and some of the longest glance durations, pointing to more extended visual engagement with items that were less predictable or less meaningful. By comparison, related primes were associated with relatively efficient processing, with shorter glances and fewer fixations than the more demanding conditions.

The correlation analyses helped to clarify how fixation behaviour was linked to reaction time. Across all conditions, total fixation duration and first fixation duration were strongly and positively correlated, indicating stable fixation behaviour: participants who looked longer at the target on their first fixation also tended to spend more time on it in total. The relationships between fixation measures and reaction time were weaker and depended on condition. Small but significant negative correlations between fixation duration and reaction time appeared only in some conditions (particularly unrelated primes and fillers), meaning that, in those cases, longer fixations were associated with slightly faster responses. In pseudo and neutral conditions, however, fixation duration did not reliably predict how quickly participants responded. Fixation count did not show a clear relationship with reaction time in any condition.

Taken together, the findings for Chapter 4 show that prime type and prime–target relationship influence both performance and eye movements. Conditions with meaningful or familiar relationships (especially related and neutral) tend to support faster and efficient processing, while fillers and, in some respects, pseudowords demand more effort and attention. At the same time, the impact of fixation measures on reaction time is small and varies by condition rather than being uniform. These results form the basis for the discussion in Chapter 5, where they are interpreted in light of previous research on priming, attention, and phrasal verb processing, and their implications for second language learning are considered.

Chapter 5: Conclusions

This chapter presents the main empirical findings of the thesis, which investigated how advanced English learners whose mother tongue is Farsi allocate attention while reading phrasal verbs. Using an eye-tracking device combined with a lexical decision task, the study examined two key factors: (1) the effect of prime–target pairs, and (2) the processing of phrasal verbs. The study scrutinized participants’ reaction times in lexical decision tasks where primes were phrasal verbs and targets were single words, particularly verbs. The experiment included five categories of prime–target pairs: related, unrelated, neutral, pseudo-words, and control.

The results build on previous research showing that eye movements are influenced by lexical properties such as word length and frequency. In line with this, the present study demonstrated that phrasal verbs demand greater attentional resources than single words, and that priming influences early fixation patterns. The methodological approach generated a rich dataset of eye movement behaviour, which was carefully processed and categorized. Analyses of fixation counts, first fixation durations, total fixation times, and saccades provided detailed evidence of how second-language readers distribute their attention in real time.

These results suggest that semantic relationships can guide attention and streamline lexical access for advanced L2 learners, even when phrasal verbs are involved. At the same time, the slower performance in unrelated and filler conditions highlights the persistence of explicit, resource-demanding processing when facilitative cues are absent. In this way, the study illustrates the coexistence of both implicit and explicit mechanisms in L2 word recognition.

Rather than pointing to categorical difficulty with phrasal verbs, the evidence underscores the role of semantic context in shaping attention and processing efficiency in word recognition process. This has both theoretical implications for models of bilingual lexical processing and pedagogical implications for the teaching of multiword expressions in English.

The integration of eye-tracking data and lexical decision responses in this study offers a nuanced view of how L2 readers process phrasal-verb primes and their influence on subsequent verb recognition. While each research question targeted a specific dimension of this process—attention allocation, response timing, and processing depth—the broader pattern reveals an interplay between early attentional demands and later processing efficiency.

One notable outcome was that related and neutral conditions prompted longer first fixations, which could seem counterintuitive given their semantic coherence. However, this aligns with prior research suggesting that the presence of a phrasal verb, especially one briefly flashed (50 ms), momentarily disrupts the baseline flow of attention (Wisintainer & Mota, 2018; Bonin et al., 2013). These early effects likely reflect low-level processing demands tied to parsing a multi-word prime or resolving its structure. Yet, the significantly shorter total fixation durations and reaction times observed for these same conditions suggest that once initial parsing is complete, semantic or associative links facilitate faster and more confident decision-making (Conklin & Schmitt, 2012; Andreou & Gkantaki, 2025; Sonbul, 2015).

This dual-stage profile supports hybrid models of lexical processing, such as Cacciari and Tabossi's (1988) account of idiom comprehension and Libben and Titone's (2008) psycholinguistic model of multi-word expression processing. These models allow for both holistic and compositional mechanisms to operate in tandem, depending on familiarity, context, and task demands. The findings from this study provide empirical support for this flexibility, especially in an L2 context where learners may rely more heavily on bottom-up cues when semantic expectations are violated (e.g., in filler or pseudoword conditions).

The pseudoword and filler conditions added further depth to the interpretation of implicit vs. explicit processing. Although pseudoword targets led to the slowest reaction times, their accuracy remained high—suggesting that learners did not guess but instead applied effortful, controlled processing. This aligns with Evans' (2008) dual-systems theory and recent studies in second language processing (VanPatten & Smith, 2022),

which emphasize that learners may alternate between automatic and deliberate strategies depending on input familiarity and cognitive load.

Moreover, the moderate-to-strong correlation between fixation metrics and reaction times validates the use of eye-tracking as a sensitive proxy for processing difficulty (Godfroid, 2025; Hu et al., 2024). This highlights the added value of combining physiological and behavioral data to assess cognitive effort in real time. The design of this study—brief prime exposure, complex semantic relationships, and controlled timing—mirrors authentic processing challenges in L2 reading, strengthening the ecological validity of the findings. Taken as a whole, the present research offers a more refined understanding of how semantic priming and attentional allocation interact during phrasal-verb processing in a second language. It bridges gaps between contradictory findings in the literature by showing that cost and facilitation are not mutually exclusive but unfold across different stages of word recognition. This supports a shift away from binary models of difficulty and toward more dynamic, temporally sensitive frameworks in applied psycholinguistics.

5. 1. Theoretical and practical implications

The results of this study add to our understanding of how priming and processing work with phrasal verbs, but they also suggest that things are more complicated than expected. Normally, we think of semantic relatedness as the main factor that speeds up recognition (Perea & Rosa, 2002). In my data, though, it was not always the related condition that produced the fastest reaction times. Neutral primes sometimes led to even quicker responses. This shows that priming effects are not only about meaning; they may also come from general processing fluency or simply from the lack of interference in neutral trials (Hoedemaker & Gordon, 2014).

The eye-tracking results back this up. Shorter fixations in the related and neutral conditions suggest smoother lexical access, while longer and more frequent fixations in other conditions signal higher processing demand (Negi & Mitra, 2020; Stupina et al., 2018). The pseudoword condition is especially interesting: it gave the highest accuracy but also the slowest responses. This pattern suggests that participants slowed down to check carefully before deciding, which fits with dual-process models of cognition—

fast, automatic responses on the one hand, and slower, deliberate strategies on the other (Evans, 2008; Van Overwalle, 2013). By contrast, the filler condition, which combined low accuracy with slower responses, seems to show what happens when there is no meaningful association to rely on: participants hesitate and often make mistakes.

This study contributes to the growing body of psycholinguistic and SLA research exploring how multi-word expressions, such as phrasal verbs, affect lexical processing. By using phrasal verbs as briefly presented (50 ms) prime stimuli, the research examined their influence on attention allocation and subsequent target verb processing. The results indicated that related and neutral phrasal verb primes facilitated significantly faster reaction times and reduced fixation durations compared to unrelated or filler primes. These findings suggest that even subliminal exposure to semantically or structurally coherent multi-word units can support more efficient lexical access to target words (Williams & Rebuschat, 2024; Hu et al., 2024).

This facilitation is consistent with theories of semantic priming, where a prime activates related lexical or conceptual representations, enabling faster recognition of the target (Perea & Rosa, 2002). However, the fact that neutral primes sometimes led to faster responses than related ones highlights the role of processing fluency and reduced interference, in line with broader models of automaticity in lexical decision-making (Godfroid and Hui, 2025). Additionally, the pseudoword condition, which showed slower reaction times but higher accuracy, reflects the engagement of explicit, controlled processing, likely triggered by unfamiliar or irregular structures. This contrast between speed and accuracy supports the dual-process account of cognitive processing—implicit (fast, automatic) vs. explicit (slow, effortful) mechanisms (Evans, 2008; VanPatten & Smith, 2022).

Importantly, this study provides new evidence that phrasal verbs, though often taught as discrete vocabulary items, function as integrated units capable of priming semantically and structurally related lexical items. The use of eye-tracking further supports this, as fixation duration and count closely aligned with reaction time outcomes, suggesting that attention and processing fluency are deeply connected in implicit lexical activation (de-la-Peña, 2024; Stupina et al., 2018). These results

reinforce the notion that multi-word expressions play an active role in real-time language comprehension and should be considered within broader models of lexical processing.

From an instructional standpoint, the findings suggest that even brief, non-conscious exposure to phrasal verbs can influence the efficiency of processing related single-word targets. In language learning contexts, this highlights the potential value of implicit learning mechanisms, especially for multi-word expressions that are often difficult to teach explicitly. The faster reaction times observed with related and neutral primes point to the benefits of presenting phrasal verbs in semantically coherent and non-disruptive contexts, which may facilitate automatic lexical access over time (Williams & Rebuschat, 2024; Godfroid & Hui, 2025).

Moreover, the impaired performance in the filler and unrelated conditions suggests that exposure to incongruent or misleading primes may interfere with learning and processing. This has practical implications for the design of instructional materials, where contextual coherence and semantic alignment between phrasal verbs and their surrounding content may reduce cognitive load and improve comprehension. For instance, embedding phrasal verbs in meaningful, context-rich input can promote deeper processing and stronger associative links between language units (Ishikawa, 2024).

The integration of eye-tracking measures provides further pedagogical value. Metrics such as fixation duration and count offer a real-time window into learners' attentional engagement and processing strategies. As suggested by Hu & Aryadoust (2024), this opens possibilities for adaptive learning systems or data-informed feedback that detect when learners are engaging more effortfully and might benefit from explicit instruction. Another practical takeaway is the value of eye-tracking in educational diagnostics. Since fixation metrics reliably reflect processing effort, teachers and researchers could use eye tracking—or its simplified proxies—to assess whether learners are engaging with verbal stimuli in a more automatic or effortful way. This insight could inform personalized learning feedback or adaptive instruction tailored to the learner's processing strategies.

In sum, the findings support a balanced pedagogical approach: providing implicit, scaffolded exposure to semantically supportive multi-word expressions, while also incorporating explicit instruction when learners encounter unfamiliar or misleading input. Such an approach is consistent with the dual-route nature of language processing revealed in this study, and may help L2 learners develop both fluency and accuracy in lexical comprehension and decision-making.

5. 2. Limitations of the study

While this study offers valuable insights into the cognitive processing of phrasal-verb primes using both eye-tracking and behavioral data, certain limitations must be acknowledged. First, the study employed an SMI RED 60 Hz eye-tracker, which, while suitable for general fixation-based analysis, may lack the temporal resolution of higher frequency devices (e.g., 120 Hz or 250 Hz). This could limit the precision of micro timing data, especially in rapid reading tasks or for detecting saccades. Additionally, the visual presentation used a relatively large font size (20 pt) to ensure legibility, which may have influenced eye movement behavior by altering natural reading dynamics such as fixation span or word skipping patterns.

Another limitation lies in the design of the prime stimuli, which were exclusively phrasal verbs. While this aligns with the study's focus, it restricts the generalizability of findings to other types of multi-word expressions or simple verbs. Furthermore, only five prime-target conditions were used (related, unrelated, neutral, pseudoword, filler), which, while theoretically motivated, may not fully capture the nuanced spectrum of semantic and syntactic variation.

The prime duration was set at 50 milliseconds, which may seem brief; however, prior research confirms that such exposure is sufficient for unconscious semantic processing (e.g., Perea & Rosa, 2002), and even 3 milliseconds has been shown to suffice for visual perception of simple stimuli (Potter, 2012). Nevertheless, differences in prime duration could influence the depth of processing and should be considered in future replication studies.

In addition, all participants in this study were Persian-speaking L2 learners of English. While this allowed for consistency in L1 background and controlled for cross-linguistic influence, it also limits the generalizability of the findings to learners from other language backgrounds. Semantic priming and phrasal verb processing may interact differently depending on the typological features of the first language, particularly in languages that lack verb-particle constructions or differ in morphological transparency.

Lastly, while a lexical decision task is a common method in psycholinguistic research, it is still an artificial task and may not fully reflect naturalistic language use. Participants' responses might be influenced by task-specific strategies, limiting ecological validity. Future studies could consider embedding phrasal verbs in sentence level contexts or using reading-for-comprehension tasks to better simulate authentic language processing.

5. 3. Further Research

While the current study provides valuable insights into phrasal-verb priming and L2 lexical processing using eye-tracking and behavioral measures, several avenues remain open for further exploration.

First, future research could expand the scope beyond phrasal verbs to include other types of multi-word expressions (MWEs) such as idioms, collocations, and compound nouns. Investigating whether similar patterns of implicit facilitation or attentional cost emerge across different multi-word structures would provide a more comprehensive understanding of how formulaic language is processed in a second language.

Second, individual differences among L2 learners should be given more attention. Variables such as proficiency level, working memory capacity, vocabulary size, or even L2 exposure context may mediate how effectively learners process and benefit from multi-word priming. Incorporating these factors could clarify why certain learners show stronger implicit effects while others rely more on controlled strategies.

Third, the use of a 60 Hz eye-tracker in this study, while sufficient for detecting general fixation patterns, may not capture more subtle or rapid eye-movement behaviors such

as micro saccades or regressions. Future studies employing higher-resolution eye tracking systems (e.g., 120–1000 Hz) may uncover finer-grained temporal dynamics, particularly during early processing windows (e.g., the first 100 ms after stimulus onset).

Fourth, combining eye-tracking with electrophysiological measures such as event related potentials (ERP) would offer a richer, time-sensitive account of lexical and semantic processing. ERP components like the N400 could provide converging evidence for semantic activation or integration processes that complement the fixation based findings.

Finally, future studies might also experiment with varying the duration and type of prime stimuli, or introducing cross-modal priming (e.g., auditory–visual) to test whether the observed effects generalize across different presentation modalities.

To sum up, these recommendations underscore the value of continuing to explore the complex interplay between attention, priming, and lexical processing in L2 learners—ideally through multi-method, cross-linguistic, and learner-sensitive designs.

This study set out to explore how briefly presented phrasal verbs as primes influence the processing of subsequent target verbs in a lexical decision task, combining eye tracking data and behavioral measures. The findings reveal a complex interplay between semantic relatedness, attentional allocation, and processing fluency in L2 lexical recognition.

Across all three research questions, the data consistently showed that semantically related and neutral primes facilitated more efficient processing, evidenced by shorter total fixation durations and faster reaction times. Conversely, filler and pseudoword conditions introduced greater cognitive load, as reflected in longer fixations and delayed responses. The use of eye-tracking further revealed that early stages of processing may carry attentional costs— even for semantically supportive primes— while later stages benefit from implicit facilitation.

The integration of fixation metrics with accuracy and reaction time supported a dual processing perspective: when input was familiar or congruent, participants relied more

on automatic, implicit mechanisms; when it was unfamiliar or incongruent, more effortful, explicit strategies were used. These findings offer theoretical insights into how multi-word expressions, even when briefly flashed, can modulate real-time word recognition in L2 readers.

In sum, this research contributes to psycholinguistic and second language acquisition literature by showing that phrasal verbs function not just as lexical units, but as active cues in processing, capable of influencing both attention and decision-making. It also underscores the value of combining eye-tracking with behavioral data to uncover the layered, time sensitive nature of lexical processing. While certain limitations exist, the study opens promising pathways for further research into multi-word processing, learner variability, and the role of implicit mechanisms in L2 comprehension.

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APPENDICES

Appendix A Appendix A Consent form

Project: Eye tracking the process of word reading

1. I confirm that the purpose of study has been explained and that I have understood it. YES NO
2. I have had the opportunity to ask questions and they have been successfully answered. YES NO
3. I understand that my participation in this study is voluntary and that I am free to withdraw from the study at any time, without giving a reason or without consequences. YES NO
4. I understand that all data are anonymous. YES NO
5. I understand that there are no known risks or hazard associated with participating in this study. YES NO

Participant name:

Participant signature:

Date:

Researcher Signature:

Appendix B English Phrasal Verbs Familiarity Test

English Phrasal Verbs Familiarity Test

Please rate the following verbs according to their familiarity to you. If you know the definitions, please write them if not, please leave the definition part blank.

Level of Familiarity

- 1_ not at all familiar
- 2_ Slightly familiar
- 3_ Somewhat familiar
- 4_ Moderately familiar
- 5_ Extremely familiar

	Phrasal Verbs	1	2	3	4	5	The definition you may know
1	Conjure up						
2	Single out						
3	Patch up						
4	Bawl out						
5	Bounce off						
6	Burn out						
7	Ward off						
8	Call on						
9	Come into						
10	Cry off						
11	Cut down						
12	Drag on						

13	Draw up						
----	---------	--	--	--	--	--	--

14	Dress down						
15	Bliss out						
16	Smash down						
17	Crease up						
18	Figure out						
19	Hand in						
20	Fall off						
21	Hand in						
22	Harp on						
23	Have on						
24	Hash out						
	Phrasal Verbs	1	2	3	4	5	The definition you may know
25	Head off						
26	Iron out						
27	Jot down						
28	Let down						
29	Fend off						
30	Shrivel up						
31	Own up						
32	Palm off						
33	Pan out						

34	Pass off						
35	Pass out						
36	Screw up						
37	Scoop out						
38	Hollow out						
39	Squeeze out						

40	Prop up						
41	Fork out						
42	Polish off						
43	Shore up						
44	Carve out						
45	Crank out						
46	Freak out						
47	Bank on						
48	Bear on						
49	Beef up						
50	Bitch out						
51	Stop off						
52	Brew up						
53	Brush up						
54	Cast off						
55	Cast down						
56	Blurt out						

57	Choke down						
58	Choke off						
59	Conk out						
	Phrasal Verbs	1	2	3	4	5	The definition you may know
60	Cordon off						
61	Crop up						
62	Dash off						
63	Ferret out						
64	Swot up						
65	Lash out						

66	Fob off						
67	Flare up						
68	Follow out						
69	Cotton on						
70	Haul in						
71	Head off						
72	Jam up						
73	Cross up						
74	Veg out						
75	Bag out						
76	Bash in						
77	Bolster up						

80	Bunk off						
81	Sack out						
82	Dole out						
83	Conk out						
84	Sniff out						
85	Perk up						
86	Amp up						
87	Cave in						
88	Chip in						
89	Pitch in						
90	Chew out						
91	Strike down						
92	Gang up						
93	Muddle up						
94	Bump into						
95	Crack down						
96	Mix up						
	Phrasal Verbs	1	2	3	4	5	The definition you may know
97	Flip out						
98	Buy off						
99	Doss down						
100	Die out						
101	Slip up						

102	Spring up						
103	Chew on						
104	Creep up						
105	Storm out						
106	Knuckle down						
107	Boil down						
108	Freeze out						
109	Take in						
110	Size up						

Recognition Post-test

Dear Participant

Have you seen this word in the experiment? Y (YES)/N (NO) If yes, please mention
How many times?

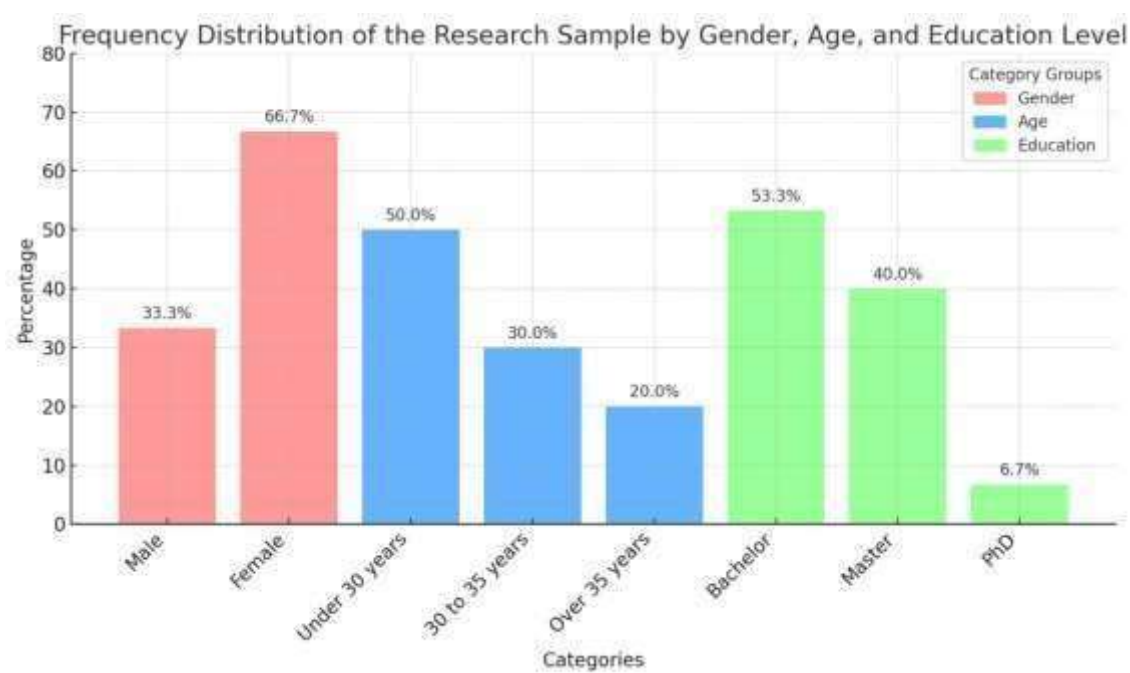
WORDS	YES	NO	How many times have you seen the word?					
amp up	Yes	No	1	2	3	4	5	6
bliss out	Y	N	1	2	3	4	5	6
fend off	Y	N	1	2	3	4	5	6
bash in	Y	N	1	2	3	4	5	6
bawl out	Y	N	1	2	3	4	5	6
blot out	Y	N	1	2	3	4	5	6
freak out	Y	N	1	2	3	4	5	6
blurt out	Y	N	1	2	3	4	5	6
bounce off	Y	N	1	2	3	4	5	6
brush up	Y	N	1	2	3	4	5	6
bunk off	Y	N	1	2	3	4	5	6
carve out	Y	N	1	2	3	4	5	6
cave in	Y	N	1	2	3	4	5	6
chip in	Y	N	1	2	3	4	5	6
chew out	Y	N	1	2	3	4	5	6
choke down	Y	N	1	2	3	4	5	6
conk out	Y	N	1	2	3	4	5	6
cordon off	Y	N	1	2	3	4	5	6

cotton on	Y	N	1	2	3	4	5	6
crank out	Y	N	1	2	3	4	5	6
crease up	Y	N	1	2	3	4	5	6
creep up	Y	N	1	2	3	4	5	6
dash off	Y	N	1	2	3	4	5	6
dole out	Y	N	1	2	3	4	5	6
ferret out	Y	N	1	2	3	4	5	6
figure out	Y	N	1	2	3	4	5	6

fob off	Y	N	1	2	3	4	5	6
flip out	Y	N	1	2	3	4	5	6
WORDS	YES	NO	How many times have you seen the word?					
freeze out	Y	N	1	2	3	4	5	6
haul in	Y	N	1	2	3	4	5	6
hollow out	Y	N	1	2	3	4	5	6
jam up	Y	N	1	2	3	4	5	6
jot down	Y	N	1	2	3	4	5	6
lash out	Y	N	1	2	3	4	5	6
whoop up	Y	N	1	2	3	4	5	6
muddle up	Y	N	1	2	3	4	5	6
line up/gang	Y	N	1	2	3	4	5	6
palm off	Y	N	1	2	3	4	5	6
doss down	Y	N	1	2	3	4	5	6
patch up	Y	N	1	2	3	4	5	6
perk up	Y	N	1	2	3	4	5	6
pitch in	Y	N	1	2	3	4	5	6

polish off	Y	N	1	2	3	4	5	6
prop up	Y	N	1	2	3	4	5	6
sack out	Y	N	1	2	3	4	5	6
scoop out	Y	N	1	2	3	4	5	6
flare up	Y	N	1	2	3	4	5	6
single out	Y	N	1	2	3	4	5	6
slip up	Y	N	1	2	3	4	5	6
sniff out	Y	N	1	2	3	4	5	6
spring up	Y	N	1	2	3	4	5	6
storm out	Y	N	1	2	3	4	5	6
strike down	Y	N	1	2	3	4	5	6
swot up	Y	N	1	2	3	4	5	6
veg out	Y	N	1	2	3	4	5	6
ward off	Y	N	1	2	3	4	5	6
screw up	Y	N	1	2	3	4	5	6
conjure up	Y	N	1	2	3	4	5	6
smash down	Y	N	1	2	3	4	5	6
Harp on	Y	N	1	2	3	4	5	6

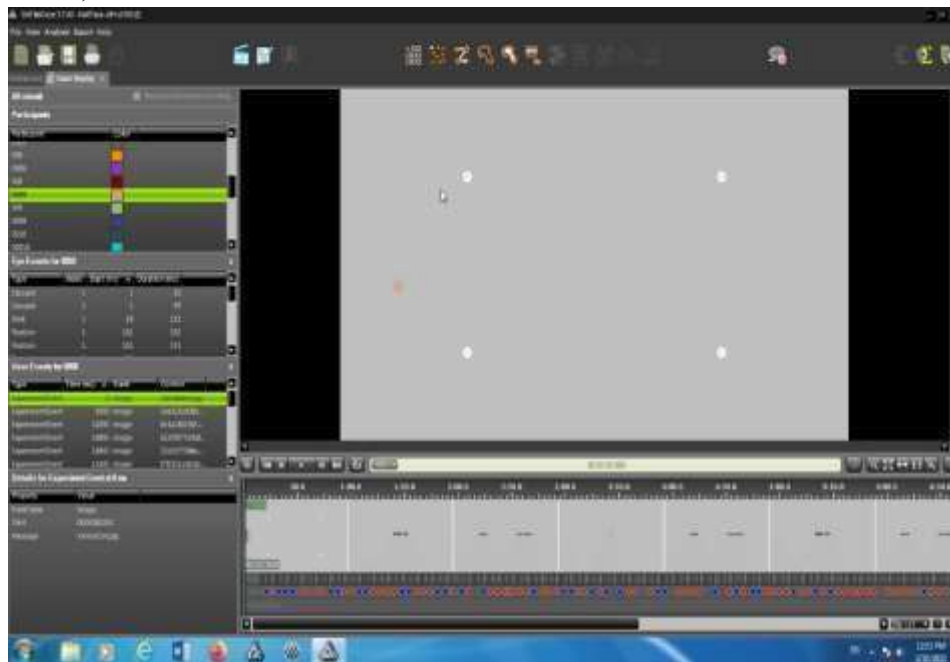
Appendix D Distribution of the research sample by gender, age, education level.



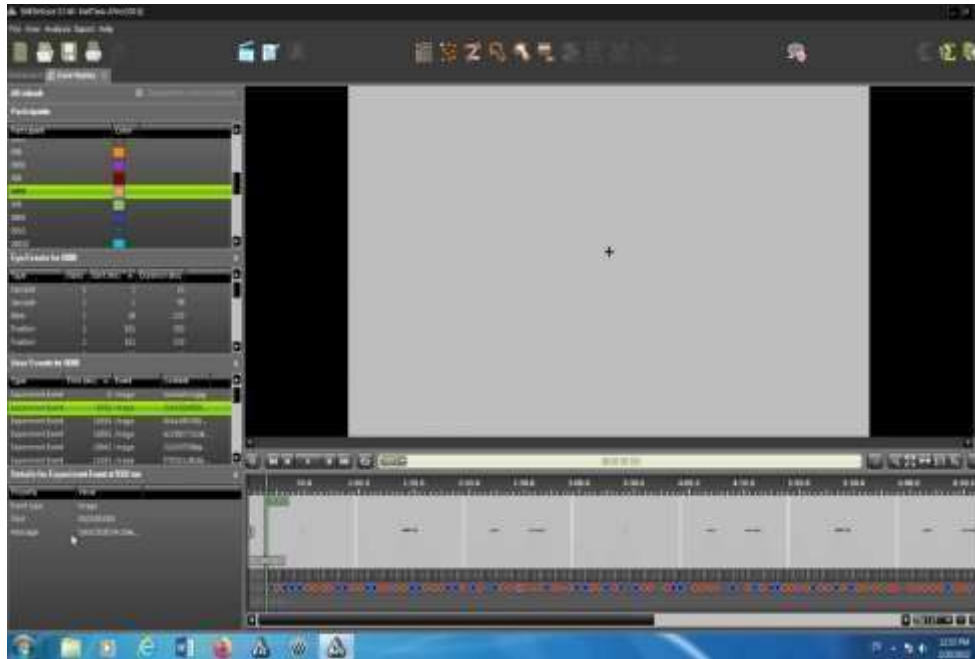
Appendix E Sample screenshots from the eye-tracking lexical decision task.

- a) Calibration
- b) Fixation cross
- c) Masked
- d) Prime
- c) Response page

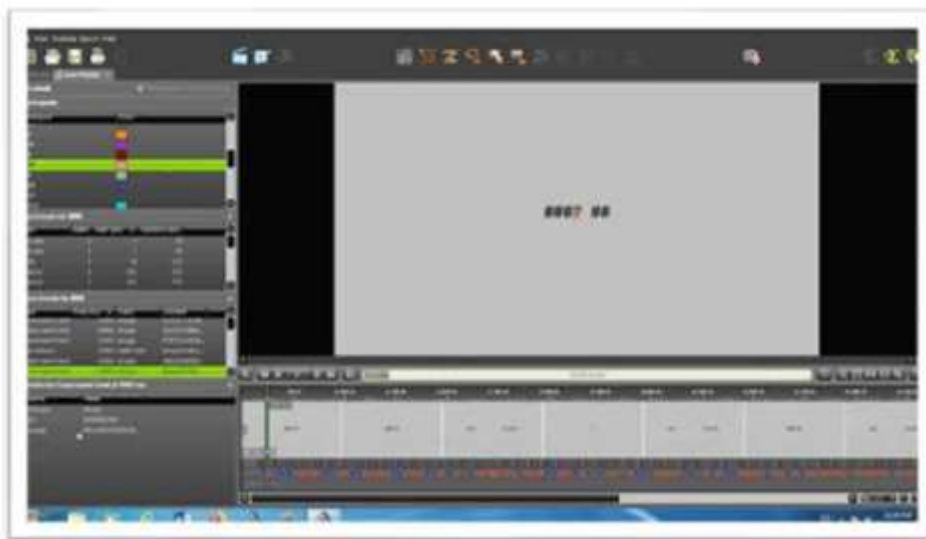
a) Calibration



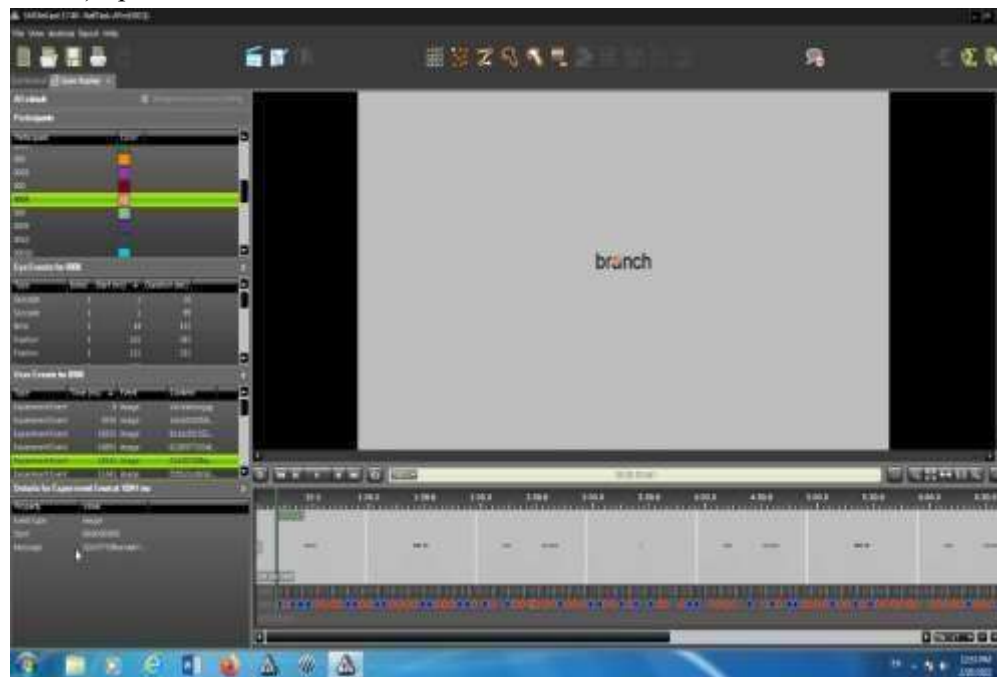
b) fixation cross



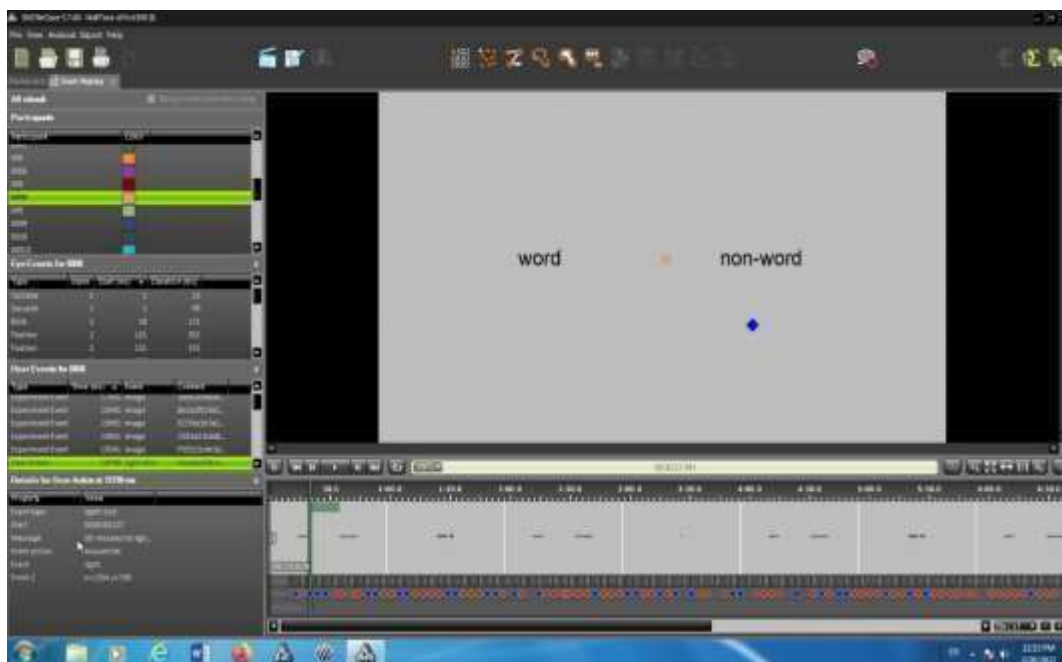
c) Masked priming



d) prime



e) response page



Appendix F Mean of reaction time by prime-target condition (Figure)

