

## Assimilation in Arabic as a Mechanism for Balancing Cognitive Loads

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### Abstract

This study explores *Idgham* (assimilation,) in Arabic as a phonological alteration process and its cognitive underpinnings. The study adopts a qualitative descriptive–analytical design to examine *Idgham* (assimilation) in Quranic recitation through the lens of Sweller’s (1988) Cognitive Load Theory (CLT). While traditional scholarship has extensively described the phonological rules governing *Idgham*, limited attention has been directed to its potential cognitive implications highlighting a gap in the literature. To reveal the cognitive implications of *Idgham* in Qur’anic recitation, this study applies Sweller’s triadic classification of cognitive load proposing that articulatory simplification in *Idgham* may reduce intrinsic processing demands accompanying complex consonant clusters. Intrinsic load associated with *Idgham* is operationalised in this study as articulatory movement complexity, and defined as the number of articulatory alterations required between adjacent consonants. The findings suggest a strong link between *Idgham* and intrinsic and germane load, and that *Idgham* minimises articulatory transitions, which may free cognitive resources potentially available for schema construction in long–term memory.

**Key words: Cognitive Load Theory, intrinsic load, germane load, *Idgham*, cognitive resources, cognitive load.**

## الادغام باللغة العربية كاستراتيجية لتقليل الجهد الإدراكي

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### الملخص

تهدف هذه الدراسة الى تسليط الضوء على الادغام باللغة العربية كعملية تغيير صوتي والاساس الادراكي لهذه العملية. تتبنى الدراسة منهج تحليلي وصفي لدراسة الادغام في القراءة القرآنية متبينة بذلك نظرية الحمل المعرفي. سلطت الدراسات السابقة الضوء على وصف احكام الادغام ولكن قليل من ذلك كان مسلط على الفائدة الادراكية للإدغام مما يشير الى ثغرة معرفية. ولأجل بيان الفائدة الادراكية تبنت الدراسة التقسيم الثلاثي للحمل المعرفي التي اقترحها سويلر. وتقتصر الدراسة ان تبسيط الحركات المطلوبة للفظ الأصوات يمكن ان يقلل الحمل الجوهري الذي قد يرافق لفظ الأصوات الصحيحة المتجاورة. الحمل الجوهري في هذه الدراسة هو درجة تعقيد حركات اللفظ. وبينت النتائج رابط قوي بين الادغام والحمل الجوهري والترابطي وان الادغام يقلل الحركات النطقية التي يمكن ان تحرر موارد ادراكية يمكن ان يتم استغلالها في عمليات ادراكية أخرى مثل تكوين مخططات معرفية تخزن في الذاكرة طويلة المدى.

الكلمات المفتاحية: نظرية الحمل المعرفي، الحمل الجوهري، الحمل الترابطي، الادغام، الموارد الادراكية، الحمل المعرفي.

### 1. Introduction

Within the rich tapestry of the Arabic language, the phonological process of Al-Idgham (assimilation) metaphorically captures the notion of one entity merging into another. This involves the blending of two successive letters with the first disappearing, partially or completely, and thereby enriching the second one.

Assimilation is a process that occurs in everyday speech, most commonly involving nasal sounds (Macmahon, 2002, p.4). This phonological process happens when a sound undergoes several phonological changes in the presence of other sounds (Ofulue et al., 2010, p. 49).

None of the above should be interpreted as suggesting that Idgham occurs without reason. Idgham occurs when two adjacent sounds, usually consonants, share common distinctive features, whether in terms

of of place, manner, or voicing, with one consonant adopting the features of the other (Dawood and Atawneh, 2015, p. 9).

Many researchers have conducted their work based on the idea that phonological changes occur when sounds appear together within the same environment, whether within the same word or across the boundaries of adjacent words. Those studies were mostly taxonomic in nature (e.g., Adhema, 1966) and contributed little to understanding the cognitive motivations behind such phonetic alterations. Notable exceptions to this propensity are recent studies that view Idgham as being based on constraints rather than rules, considering Idgham from a cognitive perspective (e.g., Al-Hashmi, 2004; Alnuqaydan, 2020; Sadeghi and Bidi, 2020; Cherifi and Guerti, 2021). Other studies focus on the rules of Idgham in Arabic, primarily to decipher those rules (e.g., Abuhamdiyah, 2016) with limited exploration of the cognitive underpinnings of the process. In fact, no study explicitly applies CLT to Idgham.

The present study addresses a theoretical gap by examining whether phonological simplification in Arabic assimilation can be interpreted within contemporary cognitive architecture models. Therefore, this work aims to investigate the phonological and cognitive foundations of this process in Quranic recitation adopting the rules of Idgham for uncovering the cognitive benefits of the phonological process. This study proposes that Idgham may function as a mechanism that potentially reduces articulatory complexity, which can be interpreted within CLT.

Building on the aforementioned, the study aims to reframe Idgham not merely as a phonological rule but as a potential articulatory strategy that aligns with cognitive economy principles. Based on that, the study addresses the questions: *How can articulatory simplification in Idgham*

*be interpreted within Cognitive Load Theory? and What are the cognitive gains obtained from this phonological alteration?*

## **2. Conceptual Framework**

This study aims to provide an overview of the phonological process known as *Idgham* (assimilation). Additionally, it will present the conceptual framework of the cognitive theory to be applied, specifically *Cognitive Load Theory*, in order to achieve the study's objectives and address the research questions.

### **2.1 Assimilation (*Idgham*)**

Assimilation in Arabic – *Idgham* refers to the merging of one sound into another, as described by scholars such as Al-Farahidi (170 A.H.), and Al-Dumyati (d. 1117 A.H.). Literally, *Idgham* is a process where the tongue adjusts to articulate two sounds simultaneously, completing the movement in a single position (Al-Zubaidi, d. 1205 A.H.). In essence, *Idgham* denotes a process where one sound is integrated into another, both being articulated with a unified movement, often with an emphasis on their articulation.

The basic conditions for *Idgham* to occur during text recitation are that the identical or similar sounds must be adjacent, with no intervening vowel (Al-Mubarrad, 285 A.H.). Additionally, the tongue must produce both sounds with one movement. Omar (2008) points out that for *Idgham* to take place, the first consonant must be *sakin* (non-vowelled) and the second *mutaharik* (vowelled).

The benefits of *Idgham*, according to Ibn Ya'eish (663 A.H.), are a reduction in the complexity that results from articulating identical or similar adjacent sounds. If these consonants were fully articulated, the tongue would need to return to the same position twice to produce two adjacent identical sounds, or it would have to move away from one position and then shift to the next consonant's position. This movement, being too close to the previous position, would create complexity in

articulation. Therefore, the Arabs resort to assimilation to simplify the tongue movement when producing adjacent sounds in connected speech. This allows the adjacent sounds to share the same place of articulation, with a single release of air for both.

## 2.2 Classification of *Idgham*

*Idgham*, as a phonological process in Arabic, has been analysed into several types based on different criteria. This led to various classifications of *Idgham*, reflecting divergent perspectives.

### 2.2.1. Classification based on the Approximation of Adjacent Consonants

*Idgham* has been classified by most Arab scholars, including Al-Mubarrad, based on the convergence of adjacent consonants in terms of their distinctive features, into the following categories:

a. **Idgham of Identical Sounds (Mutamathilayn):** This occurs when the assimilation process involves adjacent sounds that are identical in both their symbol and articulation. For instance, the Arabic word 'ردد' /rædad/ (meaning 'replied') becomes 'رَدّ' /radə/, where the two sounds are merged, and the merged sounds are pronounced with an accentuation duration longer than that required to pronounce a single letter.

b. **Idgham of Approximate Sounds (Mutaqaribayn):** This refers to two adjacent sounds that share most of their distinctive features except for one. The first sound is transformed to become more similar to the second and is then assimilated into it. For instance, in the word 'ادتعي' /idtʃæ/ (meaning 'claim') the 'd' sound is similar to the 't' sound since both are alveolar, share the same place of articulation, and are plosives. The only difference between them is in voicing. In this case, the 't' is changed into 'd' to become 'اددعي' /iddʃa/, and then the identical 'd' sounds merge to become one accentuated 'd,' resulting in 'ادعي' /idʃa/ (Al-Luhaibi, 2016, p. 481-482).

### 2.2.2. Classification of *Idgham* Based on Degree of Complexity

A second classification of *Idgham* is presented by Ibn Jinny (d. 392 A.H.) and discussed in Al-Nu'aymi (1980). According to Ibn Jinny, *Idgham* can be viewed from a different perspective. He classifies *Idgham* based on the complexity or simplicity of the assimilation process, depending on the level of effort required to complete it. Based on this distinction, *Idgham* is divided into two types:

**a. Grand assimilation (*Al-Idgham al-Kabeer*)**

Al-Dani (d. 444 A.H.) describes the phonological process of assimilation in *Al-Idgham al-Kabeer* as a compound process consisting of two steps when assimilation occurs between two adjacent vowelised consonants. The first step is the deletion of the vowel sound between the consonants, resulting in two adjacent unvowelised consonants. If the two consonants share sufficient distinctive features, the assimilation process takes place, either partially or completely. The presence of an additional step justifies classifying this type as “grand” or “major” assimilation, as opposed to the simpler type.

The following example clarifies the notion of *Al-Idgham al-Kabeer*. In the verse “Wa ltha Al-nufoosu Zuijat,” the word “nufoosu” meaning “souls” ends with a vowel. An elision of the final vowel leads to the adjacency of two consonants: one at the end “nufoosu” and the other at the beginning of the following word, “zuijat.” The “s” and “z” form a consonant cluster, which triggers the possibility of voicing assimilation, causing the “s” sound to be voiced.

Another example that demonstrates how the insertion of a vowelised sound with another can be complex and harder to apply is the word “خلقكم” /xalaqakum/ meaning “created you (pl.)” (Al-Hilali and Khan, 1996), which is pronounced “خلكم” /xalakum/. Here, the vowelised consonant /q/ is inserted in /k/, resulting in a single consonant (Al-Luhaibi, 2016).

**b. Subtle Assimilation (*Al-Idgham al-Sagheer*)**

According to Ibn Jinny (d. 392 A.H.), subtle assimilation refers to the approximation of one consonant to another without them fully merging into each other. In other words, there is no insertion of the first consonant into the second. Al-Anbari (577 A.H.) defines the term by stating that it involves assimilating a non-vowelled consonant with vowelled one to the point that they become a single accented consonant. For instance, in Surah Hud, verse 54, "إِن نَقُولُ إِلَّا إِعْتَرَاكَ", the non-vowelled /n/ is followed by a vowelled /n/. This motivates the assimilation of the two consonants into one, with the first articulated fully and the second merging into the first, leaving only its nasalised airflow, which escapes nasally.

Also, in the verse "فَإِن كَثَبُواكَ فَقُلْ رَبُّكُمْ ذُو رَحْمَةٍ وَاسِعَةٍ" (Al-An‘ām, 147), the two words "فَقُلْ رَبُّكَ" /fəqʊl rəbukə/ are sometimes mispronounced, with the phonetic features of the alveolar lateral voiced consonant ‘l’ being incorrectly replaced by those of the alveolar trill voiced ‘r’. and pronounced as "فَقْرَبُّكَ" /fəqʊrəbukə /.

### 2.3 Place and Manner of Articulation of Arabic Consonants

The Arabic language has a consonant-rich phonemic inventory with 28 consonant sounds. These sounds are articulated at various places and with different manners. To do this rich inventory justice, it is necessary to describe their place and manner of articulation in detail. For this purpose, the description of the consonants of the language in question is summarised and presented in Table 1 below as adapted from Newman(2002).

Table 1: Place and Manner of Articulation of Arabic Consonants

no.	phonetic symbol	Representative Arabic letter	Distinctive features	English counterparts
1.	b	ب	voiced bilabial plosive	B
2.	t	ت	voiceless dento-alveolar plosive	T
3.	d	د	voiced dento-alveolar plosive	D
4.	k	ك	voiceless velar plosive	K

5.	ɗ	ج	voiced palate–alveolar plosive	ɗ
6.	q	ق	voiceless uvular plosive	no counterpart
7.	l	ل	voiced alveolar lateral	L
8.	m	م	voiced bilabial nasal	M
9.	n	ن	voiced alveolar nasal	N
10.	f	ف	voiceless labiodental fricative	F
11.	θ	ث	voiceless interdental fricative	θ
12.	ð	ذ	voiced inter–dental fricative	ð
13.	s	س	voiceless alveolar fricative	s
14.	ʃ	ص	voiceless velarized alveolar fricative	no counterpart
15.	z	ز	voiced alveolar fricative	z
16.	ʃ	ش	voiceless palate–alveolar fricative	ʃ
17.	x	خ	semi–voiced uvular fricative	no counterpart
18.	ɣ	غ	voiced uvular fricative	no counterpart
19.	ħ	ح	voiceless pharyngeal fricative	no counterpart
20.	h	هـ	voiceless glottal fricative	h
21.	r	ر	voiced alveolar trill	r
22.	ʕ	ع	voiced pharyngeal fricative or approximant	no counterpart
23.	j	ي	voiced palatal semi–vowel	j
24.	w	و	voiced labio–velar semi–vowel	w
25.	t̪	ط	voiceless velarized denti–alveolar plosive	no counterpart
26.	ɗ̪	ض	voiced velarized denti–alveolar plosive	no counterpart
27.	ʕ̪	ظ	voiced velarized alveolar fricative	no counterpart
28.	ʔ	أ	voiceless epiglottal plosive	ʔ

#### 2.4 *Idgham* of Arabic Consonants

After thoroughly examining the place and manner of articulation of the consonant sounds that are members of the Arabic phonemic system, we now turn our attention to the potential assimilations between these consonants. The pairing of consonants can occur in various ways, which

Al-Mubarrad (285 A.H.) categorized based on the types of consonants involved in the process of *Idgham*. He distinguished between the *Idgham* of guttural consonants, including the glottal /ه/, the epiglottal /ء/, the pharyngeal /ع, ح/, and the uvular /غ, خ/, and the *Idgham* of oral consonants, which includes /ز, ص, س, د, ت, ط, ر, ن, ل, ض, ج, ش, ك, ق/, /م, ب, و, ف, ذ, ث, ظ/ . This study focus specifically on the *Idgham* of oral sounds, and as such, it only addresses the rules governing assimilation of oral consonants. The relevant rules are presented as follows:

- 1- *Idgham* of non-vowelled (ساكن) voiced bilabial stop /b/ with an adjacent voiceless labiodental fricative /f/.
- 2- *Idgham* of the voiced bilabial stop /b/ with an adjacent voiced bilabial nasal /m/.
- 3- *Idgham* of the voiced palato-alveolar plosive /dʒ/ with the voiceless palato-alveolar fricative /ʃ/.
- 4- Assimilation of the voiceless uvular plosive /q/ with the voiceless velar plosive /k/.
- 5- Assimilation of the voiceless velar plosive /k/ with the voiceless uvular plosive /q/.
- 6- Assimilation of the voiced velarised denti-alveolar plosive /d̪/ with the voiceless velarised denti-alveolar plosive /t̪/.
- 7- Assimilation of the voiced dento-alveolar plosive /d/ with the voiceless velarised denti-alveolar plosive /d̪/.
- 8- Assimilation of the voiced alveolar lateral /l/ in the definite article 'ال' with thirteen other consonants. Eleven of those consonants have a close place of articulation to that of the /l/; these are /t, θ, d, ð, r, z, s, ʃ, ʒ, n/ and two are articulated slightly further /ʃ, d̪/.
- 9- Assimilation of the non-vowelled voiced alveolar lateral /l/ with the voiced labio-velar semi vowel /w/.
- 10- Assimilation of the non-vowelled voiced alveolar nasal /n/ with the voiced alveolar trill /r/.

11- Assimilation of the voiced alveolar nasal /n/ with the voiced bilabial nasal /m/.

12- Assimilation of the voiced alveolar nasal /n/ with the voiced alveolar lateral /l/.

13- Assimilation of the voiced alveolar nasal /n/ with the voiced bilabial semi-vowel /w/.

14- Assimilation of the voiced alveolar nasal /n/ with the voiced palatal semi-vowel /j/.

### **2.5 Cognitive Load Theory**

This study aims to adopt Sweller's (1988) Cognitive Load Theory (CLT). This theory addresses the allocation of cognitive resources during language use, whether in learning, production, or perception (Sweller, 1988). The theory is based on the assumption that the effective allocation of cognitive resources for linguistic processes can determine the success of these processes. It builds upon the concepts of Hitch and Baddeley's (1976) model of working memory and Chi et al.'s (1981) Schema Theory by.

Sweller (1988) argues that there are three types of load that affect the allocation and consumption of the cognitive resources of a language user. First, the intrinsic load is defined as "the inherent difficulty of the material itself.". It is also viewed as the level of interaction between simultaneous elements required to achieve the learning goal. In other words, intrinsic load refers to the innate difficulty of the linguistic task, i.e. the complexity of the task.

Second, extrinsic load refers to the cognitive load related to the environment of the learning process or to unnecessary information presented to the learner. In essence, it is associated with any unneeded placed on working memory. Consequently, extrinsic load should be kept to a minimum (Sweller, 1988, 2010; Sweller et al. 2019).

Third, germane load refers to “the mental resources dedicated to learning and generating schemata in the long-term memory” (Sweller, 2010, p. 126). While intrinsic and extrinsic loads need to be lowered for successful language processing, the germane load, on the contrary, needs to be increased. Germane load is the resource used by working memory to help build new schemata in long-term memory or relate new information to existing schemata.

Cognitive Load Theory points that working memory and long-term memory are interdependent systems (Sweller, 1988). Working memory is an executive function responsible for the perceptual and linguistic processing of new information, as well as deciding whether the information received is new and need to be transferred to long-term memory or whether already exists and should be discarded (Loveless, 2022, p.4). Working memory is also responsible for controlling attention, using cognitive strategies, and retrieving information from long-term memory (Houston, 2023, p.3). The need to decrease intrinsic and extraneous cognitive load arises from the fact that working memory has a limited capacity, typically handling around seven to nine chunks of information at a time (Miller, 1956, p.81).

Sweller et al. (1998) argue that high cognitive load negatively impacts the efficiency of working memory in processing and maintaining information. A high load depletes the cognitive resources available for linguistic processing, which may ultimately affect comprehension. Regarding long-term memory, Sweller (1988) suggests that an increased load can reduce its efficiency in creating schemas. Therefore, it is advisable to reduce both intrinsic and extraneous load, while increasing germane load. This is because a higher intrinsic and extraneous load limits processing ability, while a lower germane load hinders the formation of schemas in long-term memory.

### **3. Methodology**

#### **3.1 Data of the Study**

The data used in this study include a number of Ayas (verses) that were systematically selected to represent each identified rule of *Idgham* involving oral consonants. Since the focus of the study is on the process-level analysis rather than frequency counts, one example for each rule is provided. This is sufficient since the study aims to examine the types, rather than the tokens. Cognitive load is interpreted theoretically through articulatory movement analysis rather than being experimentally measured. The selected verses are translated adopting Al-Hilali and Khan's (1996) translation. Adopting the symbols of the International Phonetic Alphabet (IPA), each verse is transcribed phonemically—, with and without assimilation—to illustrate the phonetic changes resulting from *Idgham*.

#### **3.2 Methods of Analysis**

After examining the verses where assimilation occurs, the phonetic alterations are described based on the place and manner of articulation of the consonants involved. The focus is also on the direction of assimilation, the type of change that occurs, and the final product of blending the two sounds. In light of the adopted theory, Sweller's (1988) Cognitive Load Theory, the study explores the cognitive underpinnings of the process of *Idgham*. This is performed adopting a qualitative descriptive-analytic design. The intrinsic load relative to *Idgham* would be related to the articulatory movement complexity measured by the number of articulatory shifts required.

### **4. Results and Discussion**

Learning and applying the phonological processes required in Quranic recitation, such as *Idgham*, *Ikhfaa*, etc., demands significant cognitive processing due to their complex rules and high memorisation demands, especially for novice reciters and non-native speakers of Arabic. In

contrast, for experienced reciters, those phonological rules may lead to cognitive gains, as they have overcome the difficulties of those rules through experience. In short, applying phonological rules in Quranic recitation can be a double-edged sword, resulting in either cognitive losses or gains, depending on the reciter's experience.

In line with the aims of this study, it is intended to examine the possible links between the three types of Cognitive Load Theory—namely, intrinsic, extrinsic, and germane load—and the cognitive gains achieved by applying these rules.

Cognitive Load Theory suggests that decreasing the load may increase savings in cognitive resources, which need to be allocated in a balanced way for each cognitive task to accomplish it successfully. In contrast, increasing the load may lead to depletion of cognitive resources, leaving fewer resources available for other cognitive processes, such as comprehension. Since there is a limited amount of cognitive resources dedicated to each cognitive task, it is essential to allocate those resources in a balanced way.

In this study, rather than asserting direct cognitive effects, it interprets articulatory economy as potentially aligned with reduced intrinsic load. Articulatory simplification is conceptualised as minimising tongue repositioning and release phases between adjacent consonants. Such simplification may reduce working memory processing demands during fluent recitation.

In this context, a detailed account of the possible links between *Idgham* rules and the balance of cognitive resources will be provided. This study aims to explain the benefits of phonological processes in recitation, specifically *Idgham*, through the lens of Cognitive Load Theory and the three types of cognitive load incurred in any task.

Since this study focuses on the *Idgham* rules for oral consonants, rather than those for guttural consonants, the rules for oral consonants *Idgham* and their potential connections to cognitive load are presented below:

1- *Idgham* of non-vowelled (ساكن) voiced bilabial stop /b/ with an adjacent voiceless labiodental fricative /f/: An example of *Idgham* can be seen in Al-Nisaa Sura/verse (74) ‘ومن يقاتل في سبيل الله فيقتل او يغلب’ which translates as, “And whoso fights in the cause of Allah and is killed or achieves victory, we will bestow upon him a great reward” (Al-Hilali and Khan, 1996). In this example, the words involved in assimilation are pronounced /yḁylɪbfasawfḁ/. The non-vowelled /ب/ at the end of the word “يغلب” is blended with the following /ف/ at the beginning of (فسوف) and is pronounced as one accentuated consonant (يغلفسوف) /yḁylɪf:asḁwfḁ/. *Idgham* is permitted here because both consonants have similar places of articulation, bilabial and labiodental. This represents an example of complete regressive subtle assimilation.

The cognitive benefits of this assimilation can be linked to lower articulatory movements, as both consonants are articulated from the same position: the lower lip and upper front teeth. Assimilation reduces effort in connected speech by eliminating the need to move from the bilabial position for /b/ to the labiodental position for /f/. Although the bilabial and labiodental positions are close, there is still some physical effort required to move between them. The articulation of both consonants involves the lip as the articulator, which makes advance preparation for the following consonant—necessary in rapid connected speech to save effort and time—impossible. Without *Idgham*, the lips would be occupied in articulating the stop consonant /b/. After the release phase of the stop, the lower lip moves to create a narrowing for the fricative /f/, but not before that. Therefore, assimilating both consonants and articulating them from the same position is optimal for

saving effort. This reduces the intrinsic load, since it is related to lower articulatory movements leading to less complexity of the cognitive task. Reducing intrinsic load may free cognitive resources potentially available for schema construction. This, in turn, is related to the germane load needed for storing new schemas or refining existing ones.

2- *Idgham* of the voiced bilabial stop /b/ with an adjacent voiced bilabial nasal /m/, for example, in the Al-Baqara Sura/verse 284 'ويعذب' *ويعذب* *مِنْ* *يَشَاءُ* /jʊŋəðibu mən jəʃæʔ/ (He forgives whom He wills and punishes whom He wills) (Al-Hilali and Khan, 1996). After being assimilated, it is pronounced 'ويعذمن يشاء' *ويعذمن* *يَشَاءُ* /jʊŋəðim:əjə:ʃæʔ/ with the /b/ merging into the /m/ resulting in an accentuated /m:/. The identical place of articulation and voicing justifies the tendency toward assimilation. Both consonants are produced at the same place of articulation (the lips), but as the articulation of the /b/ reaches the release phase, the air is released through the nasal cavity instead of the oral cavity, producing an elongated /m:/. This represents partial regressive assimilation, which results in effort saving.

The intrinsic load is decreased because the complex task of articulating a bilabial stop, then opening the lips and returning to the same position to produce the bilabial nasal /m/, is both effortful and time-consuming. Therefore, it is optimal to assimilate both consonants to reduce the intrinsic load associated with the complexity of articulation movements and frees cognitive resources potentially available for schema construction (the germane load). This results in the saving of cognitive resources for other tasks and helps balance the allocation of cognitive resources, making assimilation an optimal choice for cognitive efficiency.

3- *Idgham* of the voiced palato-alveolar plosive /dʒ/ with the voiceless palato-alveolar fricative /ʃ/: In the Al-Fatiha Sura/verse 29 "كزِرْعٍ أُخْرِجَ" *كزِرْعٍ* *أُخْرِجَ* /əxrədʒə ʃətʒəhʊ/, meaning "like a seed that sends its shoot" (Al-Hilali and Khan, 1996), there is an instance of idgham where the voiced

palato–alveolar plosive /dʒ/ assimilates with the voiceless palato–alveolar fricative /ʃ/. According to Al–Mubarrad (d.285), this instance of *Idgham* offers two possibilities: the sounds can either be fully assimilated or pronounced separately. Both choices are acceptable. If assimilated, the result is regressive *Al–Idgham Al–Kabeer*, and it would be pronounced as ‘أخرشطاء’ /əxrəʃ:ətʔəhu/, with the /dʒ/ being assimilated and the /ʃ/ being accentuated.

From the perspective of cognitive load, assimilating the aforementioned consonants reduces the intrinsic load by minimising unnecessary movements. Since both consonants share the same place of articulation, it would be more efficient to avoid the extra effort of moving the tongue between two positions: one for the palato–alveolar articulation of /dʒ/ and to the other for the same position when producing /ʃ/. Keeping the tongue in the same position during the articulation of both consonants, with only a partial movement at the release phase of the plosive consonant, would result in a blended production of both sounds. This approach saves cognitive effort by reducing the number of articulatory movements.

4– Assimilating the voiceless uvular plosive /q/ with the voiceless velar plosive /k/, as in the Al–Mursalat Sura/verse 20 ‘ألم نخلقكم’ /ələm nəxlɒqkɒm/ meaning “Did we not create you?” (Al–Hilali and Khan, 1996), presents two possibilities based on Sibawayh (d. 180 A.H.). One possibility is complete assimilation, leaving only an accentuated /k/, while the other is partial assimilation, where only the elevation of the /q/ is preserved with the accentuated /k/.

In the case of assimilation, the production of the /q/ is simplified by maintaining only its elevation, as it is more elevated than the /k/. The back of the tongue moves directly to the position for the velar /k/, which would be accentuated, requiring twice the time for compared to the unassimilated /k/. Reducing the number of movements needed for the

production of two adjacent consonants lowers the intrinsic load, leading to decreased cognitive effort. This results in savings of cognitive resources for the dual production process. Consequently, an amount of cognitive resources is freed available for other cognitive tasks such as schema construction.

5- Assimilating the voiceless velar plosive /k/ with the voiceless uvular plosive /q/, as in “أنهك قطنًا” /ənhək qətanə/, result in assimilation to “أنهقطنًا” /ənhəq:ətənə/, with the /q/ being accentuated. This exemplifies a process of assimilation in the opposite direction of movements described in point 4 above. The tongue is elevated for the production of /q/, which is accentuated, taking twice the time required for an unassimilated /k/. The necessity of this process in this example is justified by the fact that both consonants have a similar position of articulation, which allows for simplification by moving directly to the position of the second consonant, resulting in complete regressive assimilation.

The cognitive benefits are clear: less movement is needed for the production of the two sounds, meaning less effort for the tongue and a simple process for the working memory to handle. This results in reduced cognitive load, as fewer resources are required for the production process.

6- Assimilating the voiced velarized denti-alveolar plosive /d̪/ with the voiceless velarized denti-alveolar plosive /t̪/, as in Al-Naml Sura/verse 62 “أمن يجيب المضطر” /əmən juɖʒi:bʊ əl:muɖt̪ərə/, meaning “whoever answers the needy” (Al-Hilali and Khan, 1996), is a process involving both options: the assimilation of adjacent consonants, where the /t̪/ is accentuated /əl:muɖt̪ərə/, or the full articulation of the consonants involved.

Here the assimilation occurs within the boundaries of the same word, where blending takes place between two velarised consonants having the same place of articulation, with the only difference being voicing.

The process is complex, even though the two consonants share the same place of articulation. The reason for this complexity is that, with the full articulation of both sounds, the tongue must move away from the denti-alveolar position after producing the /d/, and then return to the same position for the /t/. Therefore, it is more efficient in terms of time and effort, as well as reducing intrinsic load, to assimilate the /d/ with the /t/, producing both consonants with a single tongue movement, resulting in an accentuated /t/. This process reduces the cognitive resources needed for the production of both consonants and frees cognitive resources that may be available for the germane load.

7- Assimilating voiced denti-alveolar plosive /d/ with the voiceless velarised denti-alveolar plosive /d̤/, as in the phrase from the Al-Nisaa/verse 167 “قَدْ ضَلُّوا” /qəd d̤ʕlu:/, meaning “they have verily strayed far” (Al-Hilali and Khan, 1996). With assimilation, the words are pronounced /qəd̤:ʕlu:/, with the /d̤/ being emphasised.

The full production of these two consonants is complex, leading to a depletion of cognitive resources during the production process. Since both consonants are produced from the same position, it is more efficient to blend them into a single, emphasised sound with one tongue movement for both. This approach reduces the effort required to leave and return to the denti-alveolar position the second consonant. In other words, the intrinsic cognitive load is lowered, and the cognitive resources consumed are also reduced, leading to a possible gain in germane load.

8- Assimilating the voiced alveolar lateral /l/ in the definite article ‘ال’ with thirteen other consonants. Eleven of those consonants have a close place of articulation to that of /l/: /t, θ, d, ð, r, z, s, ʃ, ʈ, ʣ, n/, while two are articulated slightly further from it: /ʒ, d̤/.

These consonants have various places of articulation, but are close or identical to the place of articulation of /l/. Six are alveolar, four are

denti–alveolar, two are interdental, and one is palate–alveolar. All of these consonants have the potential to be assimilated with the alveolar /l/ due to the difficulty of moving the tongue from one position and then returning to the same or a close position for the second consonant in cases of full articulation. The assimilation of /l/ with the neighbouring consonant that has an identical or close place of articulation provides benefits by making the production of the two consonants less complex, thus consuming fewer cognitive resources. This reduces cognitive load; as fewer movements are made during the articulation of neighbouring consonants.

9– Assimilating a non–vowelled voiced alveolar lateral /l/ with two other consonants occurs in two instances: first, with the voiced labio–velar semi–vowel /w/, as in the Al–Baqara Sura/verse 282 "فَلْيَكْتُبْ" /fəljəktʊb/. By assimilation, the two consonants become /fəlj:əktʊb/, with the /j/ being accentuated; second, with the voiced alveolar trill /r/, as in Al–Israa Sura/verse 24 "وَقُلْ رَبِّي" /wəqʊl rəbi/, which becomes /wəqʊr:əbi/, with the /r/ being accentuated.

The decrease in articulation complexity is evident in the fact that both consonants are articulated with a single movement of the tongue, as both approach the hard palate for the production of the second palatal consonant. This leads to the accentuation of the /j/, which is produced with twice the duration required for an unassimilated /j/. This process result in a reduction in intrinsic cognitive load, thereby conserving cognitive resources for other cognitive tasks such as schema construction.

10–Assimilating the non–vowelled voiced alveolar nasal /n/ with the voiced alveolar trill /r/, as in the Al–Najim Sura/ verse 23 "مِّنْ رَبِّهِمْ" /minrəbihim./ meaning “from their Lord” (Al–Hilali and Khan, 1996), results in complete assimilation of the /n/. The words are pronounced /mir:əbihim/, with the emphasis on the /r/. The same place of

articulation, that is, alveolar, justifies the assimilation of /n/ and /r/. The change occurs in the manner of articulation, where both sounds are produced as an alveolar trill, with no *ghunna* /ʁʊn:ə/ (nasalisation) of the /n/.

This leads to a decrease in cognitive load by producing both consonants with a single tongue movement and eliminating the *ghunna* of the /n/, which is characteristic of nasal sounds. Lowering the cognitive load results in saving cognitive resources potentially available for the germane load.

11–Assimilating the voiced alveolar nasal /n/ with the voiced bilabial nasal /m/, as in the Al–Qalam Sura/verse 46 "فهم من مغرمٍ مُتقلون", meaning "they are in love and burdened". The words involved "من مغرمٍ", are pronounced /mim:əʁəmin/, with the /m/ being emphasised and the /n/ undergoing partial assimilation, leaving only its nasalisation. This represents the *Idgham* of two nasal sounds that are both voiced, meaning they are identical in their phonetic features except for the place of articulation. The proximity of the positions where each consonant is articulated justifies the need for assimilation in phonetic terms.

In cognitive terms, the assimilation is justified for reducing cognitive load and increasing efficiency in cognitive recourses. This leads to an extra amount of cognitive resources possible available for the germane load.

12–Assimilation of the voiced alveolar nasal /n/ with the voiced alveolar lateral /l/, as in the Al–Waqi’a Sura/verse 85 "ولكن لا تبصرون" /wəlakin la/, meaning "but you do not see" (Al–Hilali and Khan, 1996). The words are pronounced /wəlakil:æ tʊbsɪru:n/, with the /n/ completely disappearing after undergoing full assimilation. The /l/ is accentuated and takes the duration of two phonemes in pronunciation. Assimilating the /n/ with the /l/ occurs with no *ghunna*. Phonetically, the need for assimilation is justified by the proximity of the places of articulation of both consonants (alveolar), which makes it difficult for the tongue, in

case of full articulation, to move away from the alveolar ridge and then return to it for the production of the adjacent sound /l/.

In cognitive terms, articulating two adjacent consonants with one move conserves cognitive resources by decreasing cognitive load and lowering the complexity of production. This results in further gains by increasing amount of cognitive resources available for the germane load.

13- Assimilation of the voiced alveolar nasal /n/ with the voiced bilabial semi-vowel /w/, as in the Al-Ra'd Sura/ verse 11 “مِنْ وَالٍ” /minwalin/, meaning “a protector” (Al-Hilali and Khan, 1996) occurs when the adjacent consonants are pronounced /miw:alin/, undergoing partial assimilation. . The /n/ retains only its nasalization, while the /w/is accentuated. The production of the /n/ is omitted, and the articulators prepare immediately for the articulation of /w/, leaving only the *ghunna* of the /n/ and accentuating the /w/.

The cognitive benefits of this process stem from the reduced effort required to produce two adjacent consonants, resulting in a decrease in cognitive resource consumption and frees cognitive resources potentially available for the germane load.

14-Assimilation of the voiced alveolar nasal /n/ with the voiced palatal semi-vowel /j/, as in the Al-Zalzala Sura/verse 7 “مَنْ يَعْمَلْ” /mən jɛmɔl/, meaning “anyone who has done work” (Al-Hilali and Khan, 1996). Here, the adjacent consonants are pronounced /mɔj:ɛmɔl/, undergoing partial assimilation, with only the nasalisation of the /n/ being retained and the /j/ being accentuated. The close place of articulation creates the possibility of assimilating the two sounds for cognitive benefits, reducing intrinsic load while freeing cognitive resources available for other cognitive tasks such as the germane load.

## 5. Conclusions

This study explores the need for phonological alterations, such as *Idgham* in Quran recitation, through a cognitive lens. To uncover the cognitive underpinnings of *Idgham*, the study adopted Sweller's (1988) Cognitive Load Theory and his classification of cognitive load into intrinsic, extrinsic, and germane load. The contribution of this work is that it is the first to integrate CLT with Arabic assimilation. Also, this study proposes an articulatory–cognitive interface. With this objective in mind, the study reached the following conclusions:

1– There is an inseparable relationship between the need for phonological alteration processes, such as *Idgham*, and the balance in the allocation of cognitive resources.

2– *Idgham* helps decrease the complexity of sound articulation, reducing intrinsic load and leading to savings in cognitive resources.

3– The reduction in intrinsic load, in turn, helps increase germane load, which is a necessary resource for long–term memory.

4– *Idgham* can be used by experienced reciters as a strategy for reducing the depletion of cognitive resources due to high intrinsic load, thereby increasing the germane load needed for building new schemas in long–term memory or modifying existing ones.

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